SMART CALL BOX FIELD OPERATIONAL TEST EVALUATION

SUBTEST REPORTS

James H. Banks
Civil and Environmental Engineering Department

Patrick A. Powell
Electrical and Computer Engineering Department

San Diego State University
San Diego, CA 92182

May 1, 1997

ABSTRACT

Smart call boxes are an enhanced version of devices used as emergency call boxes in California. The overall system consists of a microprocessor, a cellular communications transceiver, solar power sources, data collection devices, maintenance computers, and data recording systems. The Smart Call Box Field Operational Test (FOT) evaluated the feasibility and cost-effectiveness of using smart call boxes for five data processing and transmission tasks: traffic census, incident detection, hazardous weather reporting, changeable message sign (CMS) control, and video surveillance. In addition, institutional issues were analyzed as a part of the FOT. This report presents detailed evaluation results for the individual subtests. A separate Summary Report presents an overview of the FOT. Most of the traffic census systems functioned adequately but suffered from reliability problems. None of the incident detection systems functioned correctly, but the problems appear to be minor. Hazardous weather detection and reporting systems functioned adequately, but could be improved by several proposed design enhancements. The CMS Control subtest was canceled prior to the installation of field equipment; typical CMS designs appear to be incompatible with smart call box control. Monochrome video installations intended to verify visibility conditions and CMS messages functioned adequately; a color system intended for incident verification provided adequate image quality but was inadequate for incident verification due to a slow refresh rate and lack of pan-tilt-zoom control. Important institutional issues related to deployment include market size and profitability; procurement models; and call box ownership, financing, and maintenance. Institutional issues related to the FOT itself include its basic organizational structure and contracting procedures.

Key words: intelligent transportation systems, field operational tests, call boxes, traffic data collection, wireless communications, institutional issues, cost-effectiveness.

EXECUTIVE SUMMARY

Smart call boxes are an enhanced version of devices used as emergency call boxes in California. The overall system consists of a microprocessor, a cellular transceiver, a solar power source, data collection devices, a maintenance computer, and data recording systems. The goal of the Smart Call Box Field Operational Test (FOT) was to demonstrate the feasibility and cost-effectiveness of using smart call boxes for five data processing and transmission tasks: traffic census, incident detection, hazardous weather detection and reporting, changeable message sign (CMS) control, and CCTV surveillance. In addition, institutional issues were analyzed as a part of the FOT. Test systems were designed and installed by two vendors, GTE Telecommunications Systems of Irvine, California and U. S. Commlink of San Leandro, California. This report presents detailed evaluation results for the individual subtests. A separate Summary Report presents an overview of the FOT.

Traffic Census

Five system configurations were tested. External-counter loop-detector systems (that is, systems employing loop-detector counters installed outside the call box cabinet) were developed by both vendors, as were internal-counter loop-detector systems (systems in which the counters were installed inside the call box cabinets). In addition, U. S. Commlink developed a system that employed an infrared-detector counter. All systems except the infrared detector system functioned adequately, but there were reliability problems with all but one of the units. All but one of the U. S. Commlink units required external A/C power. Capital costs of the systems tested are expected to vary widely, depending on the type of system, the cost of providing A/C power if required, and the cost of installing detectors. Costs of loop-detector systems, exclusive of A/C power and detector installation, range from $3,500 to $10,500. The cost of the infrared system was $17,700 exclusive of A/C power costs. Maintenance costs could not be determined; however, in most cases life cycle costs of the loop-detector systems tested would have been less than those of comparable hardwire systems, provided annual maintenance costs do not exceed $500 to $1,000 per unit. Smart call box traffic census systems are definitely feasible, and will often be cost-effective when compared with comparable hardwire systems; they may not be cost-effective when compared with other systems involving wireless communications, such as special-purpose systems consisting of traffic counters, solar power supplies, and cellular modems. Such systems should be cheaper, and may avoid some of the system integration problems encountered in the FOT. In particular, the systems tested made little use of the call box microprocessor, but its presence may have complicated the system integration problems.

Incident Detection

"Incident detection" systems tested in the FOT were actually intended to detect traffic congestion only, as opposed to distinguishing incident congestion from recurrent congestion. Systems were designed to transmit alarms when speed thresholds of 50 MPH

and 40 MPH were crossed. Three different system configurations were tested. GTE developed an internal-counter system; U. S. Commlink developed external-counter and infrared counter systems. None of these systems functioned adequately. The GTE systems never transmitted any alarms, although congested traffic is known to have been present. The U. S. Commlink infrared counter did transmit alarms, but these did not correspond well to known traffic conditions. The U. S. Commlink external counter system functioned somewhat better than the other systems, but still sometimes failed to transmit alarms when congested traffic was present. Since the U. S. Commlink systems were installed very late in the FOT, there was little time to correct design errors. The problems with the U. S. Commlink external-counter system appeared to be comparatively minor, and it is possible that they might have been corrected had more time been available. Capital costs for the incident detection systems are similar to those for comparable traffic census systems. Further development and testing of these systems will be required prior to deployment to correct design defects and establish their reliability. As in the case of traffic census systems, other system architectures involving wireless communications should also be considered.

Hazardous Weather Detection and Reporting

Three hazardous weather detection and reporting systems were tested. Both GTE and U. S. Commlink developed low-visibility alarm systems based on Jaycor visibility sensors. In addition, U. S. Commlink developed a wind speed alarm system based on a Davis Weather System. The GTE visibility alarm system was installed in September 1995. It functioned adequately, transmitting numerous alarms beginning in November 1995. It also appears to have been reliable. The U. S. Commlink visibility alarm system was not installed until April 1996, and never transmitted an alarm in the field, presumably because fog was no longer present by that time of year. The U. S. Commlink wind speed alarm system was also installed in April 1996; it functioned adequately for a period of about six weeks. No reliability problems were experienced with this system, but the period of observation was too short to draw conclusions about its reliability. Capital costs were about $3,000 for the wind-speed alarm system and $5,000 for the low-visibility alarm system. In most cases life cycle costs will be less than those of comparable hardwire systems provided annual maintenance costs do not exceed about $7,500 per unit. Although these systems were relatively successful, further development and testing should take place prior to widespread deployment. Goals should be to 1) provide multiple alarm levels and all-clear signals for all systems, 2) modify the GTE system to incorporate sensor verification and the ability to download sensor data, 3) provide for transmission of character string alarm messages rather than FAX messages, 4) develop software to record and display alarms at the TMC, and 5) design networks of visibility alarm systems that can provide advance warning of the approach of fog.

Changeable Message Sign Control

This subtest was canceled prior to the installation of field equipment. The test was originally expected involve use of smart call boxes to evaluate alarm conditions (such as incidents or hazardous weather conditions) and post preprogrammed warning messages on CMSs. This proved to be impractical for two reasons: 1) TMC personnel in the San Diego area objected to the use of preprogrammed CMS messages on the grounds that the messages required are two complex and variable to allow preprogramming; 2) the Model 500 CMS used in California is not suitable for control by a smart call box. The Model 500 CMS employs an external controller (a Model 170 traffic controller) to switch the lights in the sign matrix. This cannot be replaced by a smart call box, because the amount of wiring required exceeds the physical connectivity limits of the call box. An alternative CMS design would integrate the light-switching unit into the sign itself. In either case, the most obvious architecture is to have software at the TMC generate a bit map indicating which lights are to be on and transmit this directly to the light-switch controller. This architecture requires a communication link, but no additional data processing capability in the field. Remote control of CMSs using cellular modems and Model 170 controllers has already been demonstrated in California, independent of this FOT, and use of cellular modems with internally-controlled CMSs should also be feasible. Consequently, there is no need to develop smart call box systems to control CMSs.

CCTV Surveillance

Two systems developed by U. S. Commlink were tested. One of these was a monochrome fixed-field of view (FFOV) system intended to verify visibility conditions and CMSs messages. The other was a color system intended to verify incident conditions. The color system employed a pan-tilt-zoom (PTZ) camera, but did not provide for remote control of this unit; hence, the overall system functioned as fixed field of view. Both systems transmitted compressed video signals; refresh rates varied from 8 to 40 seconds per frame, depending on the size of the image. Both systems were installed very late in the FOT. The monochrome system functioned adequately, but experienced equipment failures that had not been corrected by the end of the FOT. The color system provided images of adequate quality, but San Diego TMC representatives stated that it was inadequate for incident verification due to the slow refresh rate and lack of PTZ capability. Reliability of the color system was adequate during the short period it was operational; however, the period of observation was too short to permit conclusions about its reliability. All systems tested required A/C power. Capital costs, exclusive of the cost of supplying power, were around $4,000 to $5,000 for the monochrome system and $13,500 for the color unit. Life cycle costs for these systems will be less than those of comparable hardwire systems provided annual maintenance costs do not exceed about $1,000 per unit. Further development and testing of the monochrome system is recommended to 1) correct the problems leading to equipment failure; 2) evaluate reliability and maintenance costs; and 3) develop a version of the system that does not require external A/C power.

Institutional Issues

Institutional issues were evaluated based on information from documentary sources, interviews with participants, and the experience of the Evaluator as a participant in the FOT. Issues included those expected to impact the deployment of smart call box systems as well as those encountered in the FOT itself. Recommendations for overcoming potential institutional barriers to deployment include 1) Vendors should carry out quantitative market research to better identify the potential market for smart call boxes; 2) Agencies considering deployment of smart call boxes should carry out deployment planning to resolve issues related to the basic procurement model (in-house or privatized), call-box ownership, financing, maintenance, data distribution, potential environmental impacts and community concerns, permit requirements, contracts with cellular carriers, and incorporation of data into existing traffic databases; and 3) Agencies should investigate the qualifications of prospective vendors, especially financial health, commitment to the project, and level of dependence on subcontractors. Issues related to the conduct of the FOT included its basic organization and contracting procedures. The FOT involved separate contracts between 1) the sponsors and San Diego Service Authority for Freeway Emergencies (SAFE), acting as agent for the FOT partners; 2) San Diego SAFE and the Project Manager; 3) San Diego SAFE and the vendors; and 4) the sponsors, the Statewide Evaluator, and the Local Evaluator. Contract processing was a major source of delay. A more appropriate organizational model might have been to include the Project Manager and the vendors in the FOT partnership and to have involved the Local Evaluator in preparation of the FOT proposal.

TABLE OF CONTENTS

Page

Page

Page

Page

TABLES

ILLUSTRATIONS

Page

INTRODUCTION

Smart call boxes are devices similar to those used as emergency call boxes in California. They consist of a microprocessor, a cellular telephone transceiver, and a solar power source. The purpose of the Smart Call Box Field Operational Test (FOT) was to determine whether such devices are a cost-effective means of performing specified data processing and transmission tasks. The FOT was divided into the following five subtests, each focusing on a particular data processing/transmission task:

1. Traffic Census

2. Incident Detection

3. Hazardous Weather Detection and Reporting

4. Changeable Message Sign (CMS) Control

5. CCTV Surveillance

In addition, the FOT evaluation included analysis of institutional issues encountered in the FOT or likely to be encountered in the deployment of smart call box systems.

The Smart Call Box FOT was funded by the Federal Highway Administration (FHWA) and the State of California. It was carried out by a consortium (the FOT Partners) consisting of District 11 of the California Department of Transportation (Caltrans), the Border Division of the California Highway Patrol (CHP), and the San Diego Service Authority for Freeway Emergencies (SAFE).

Day-to-day management of the FOT was provided by a Project Manager. Initially, the Project Manager was the Titan Corporation; however, in March 1994 Titan sold this portion of its business to RMSL Traffic Systems, Inc. and RMSL acted thereafter as the Project Manager under subcontract with Titan. On January 1, 1996 , RMSL changed its name to TeleTran Tek Services (T-Cubed); in this report this firm will be referred to as T-Cubed throughout.

Independent evaluation of the FOT was provided by San Diego State University, under subcontract with the California Partners for Advanced Transit and Highways (PATH) program, which served as Statewide Evaluator for California field operational tests.

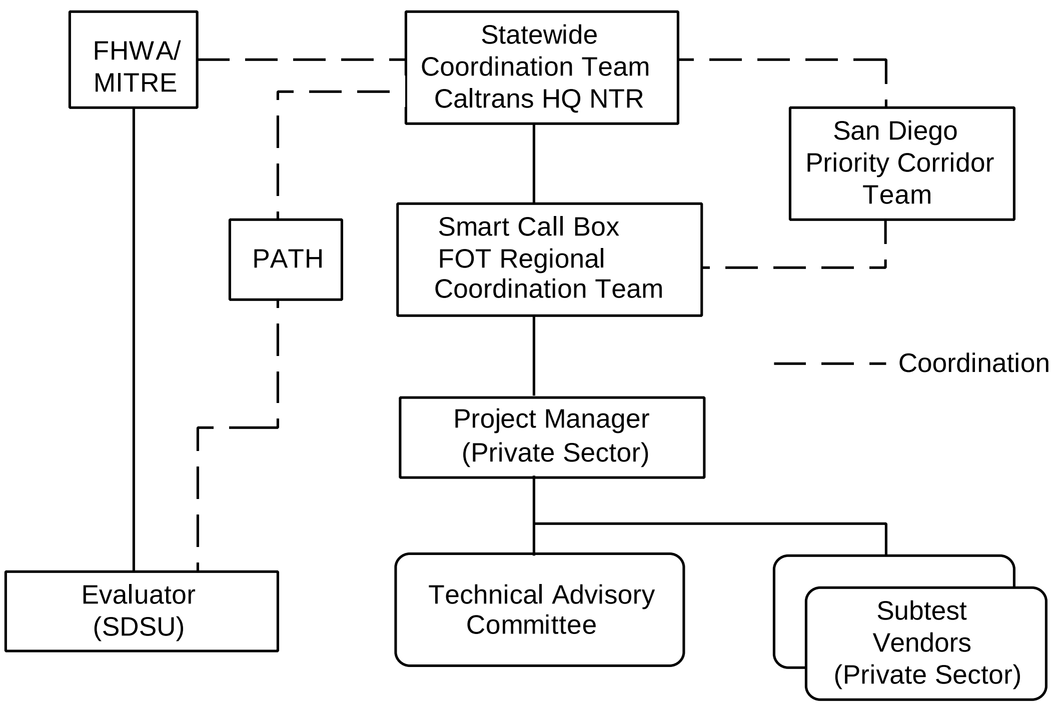
Technical supervision of the FOT was the responsibility of a Regional Coordination Team (RCT) consisting of voting representatives of the Partners and non-voting representatives of the Project Manager and the Evaluator. In addition, non-voting representatives of

FHWA, the Caltrans Office of New Technology and Research, and PATH sometimes attended RCT meetings.

Design and installation of test systems was carried out by two vendor teams under contract with the Partners. One of these teams was led by GTE Telecommunications Systems of Irvine, California. The other was led by U. S. Commlink of San Leandro, California. Appendix A gives a complete list of vendors included in the two teams. Input into the management of the FOT by the vendor teams (and, in theory, by any other interested individuals or firms) was provided by means of a Technical Advisory Committee (TAC).

Figure 1 is a schematic diagram showing the formal lines of authority and reporting among the participants in the Smart Call Box FOT.

Figure 1. Formal Lines of Reporting for the Smart Call Box FOT.



This report documents in detail the evaluation of each of the five substantive subtests and the analysis of institutional issues. An overview of the FOT evaluation may be found in a separate summary report (*1*).

TRAFFIC CENSUS SUBTEST

SUBTEST OBJECTIVES

The objective of this subtest was to evaluate the cost-effectiveness of smart call boxes for processing and transmitting traffic census data. This included determining the following:

- The relative effectiveness of several different test systems involving smart call boxes for processing and transmitting traffic census data when compared with one another and with a baseline system consisting of Peek VT-1900 traffic counters networked by hard-wire telephone to a microcomputer at Caltrans District 11 Headquarters. Effectiveness was defined to include the functional adequacy, accuracy, and reliability of the data processing and data transmission provided.

- The projected life-cycle costs of different test systems involving smart call boxes used to process and transmit traffic census data, as compared to one another and to the baseline system.

- Tradeoffs (if any) between use of the various smart call box systems and hard-wire telephone systems for the processing and transmission of traffic census data.

SUBTEST DESCRIPTION

Eight smart call box units were tested. These included a total of five different test system configurations developed by two separate vendor teams. The vendor team headed by GTE designed and installed two units. One of these employed a standard inductive loop traffic counter external to the call box and the other a loop counter installed in the call box cabinet. The other vendor team, headed by U. S. Commlink, designed and installed six units. Four of these employed standard inductive loop counters external to the call box, one employed an inductive loop counter installed in the call box cabinet, and one employed an infrared detector counter.

In all but one case, call boxes used in this subtest were also used in other subtests. In the case of the systems developed by the GTE team, the traffic census units were also used in the Incident Detection subtest. Those developed by the U. S. Commlink team were each used in one or two other subtests, except for that at U. S. Commlink Site 3. Appendix B documents overall system configurations for the two vendor teams, showing the units used in each subtest.

In each case, the overall system involved field units consisting of traffic counters and call boxes that reported to a data collection center at the Project Manager's headquarters. All the systems developed for this subtest integrated call boxes with existing traffic counting devices. With the exception of the infrared counter, these were state-of-the-art loop counters. In all cases, the major part of the information processing capability of the system resided in the counter, rather than in the call box. The counter interpreted analog signals from sensors, counted vehicles, accumulated counts over predetermined time intervals, and stored the results in memory. Call boxes were used strictly as communication devices. They functioned by activating themselves either during a preprogrammed time window or (in the case of U. S. Commlink systems) whenever they were paged from the data collection center. Once activated, they served as a data communications link to 1) download data from the counters to the data collection center and 2) transmit programming instructions to the counters from the data collection center.

The following is a detailed description of the sites and equipment included in each test system. Block diagrams showing the functioning of these systems are presented in Appendix C.

GTE Systems

- ***System Configuration: External Loop Detector***

  Equipment:

  1 - GTE Call Box
  1 - Solar Charging Assembly
  1 - Diamond Traffic Tally 2001 Counter

  Site:

  - I-8, Post Mile EB 0.214, Call Box Number 8-02T, Rosecrans On-Ramp. GTE Site # 2.

- ***System Configuration: Internal Loop Detector***

  Equipment:

  1 - GTE Call Box
  1 - Solar Charging Assembly
  1 - Diamond Traffic Phoenix Counter

  Site:

  - I-8, Post Mile EB 1.450, Call Box Number 8-16, Taylor St. - Hotel Circle. GTE Site # 3.

U. S. Commlink Systems

- ***System Configuration 1: External Loop Detector Counter***

  Equipment:

  1 - U. S. Commlink, Smart Card System
  1 - Peek, ADR 3000 Counter
  1 - Cubic Call Box Assembly
  1 - Call Box Mounting Assembly
  1- Solar Charging System

  Sites:

  - I-5, Post Mile NB 36.826, Call Box Number 5-368, North of Via de la Valle. U. S. Commlink Site # 1.
  - I-5/I-805, Post Mile NB 805 28.526, Call Box Number 805-288, at I-5/I-805 Interchange. U. S. Commlink Site # 2.
  - I-805, Post Mile NB 18.296, Call Box Number 805-184, at Murray Ridge Road. U. S. Commlink Site # 3.
  - SR-163, Post Mile NB 5.498, Call Box Number 163-52, at Kearny Pedestrian Overcrossing. U. S. Commlink Site # 4.

- ***System Configuration 2: Internal Loop Detector Counter***

  Equipment:

  1 - U. S. Commlink, Smart Card System
  1 - Peek, ADR 2000 Counter
  1 - Cubic Call Box Assembly
  1 - Call Box Mounting Assembly
  1 - Solar Charging System

  Site:

  - I-8, Post Mile EB 39.300, Call Box Number 8-392, at Japatul Road (SR-79). U. S. Commlink Site # 5.

- ***System Configuration 3: Infrared Sensor Counter***

  Equipment:

  1 - U. S. Commlink, Smart Card System
  1 - Schwartz Electro-Optics, Autosense Laser Sensor System
  1 - Cubic Call Box Assembly
  1 - Call Box Mounting Assembly
  1 - Solar Charging System

  Site:

  - I-15, NB 12.957, Call Box Number 15-124, Ammo Rd. U. S. Commlink Site # 6.

Figure 2 is a map showing the location of these sites.

Data Transmission and Processing Tasks

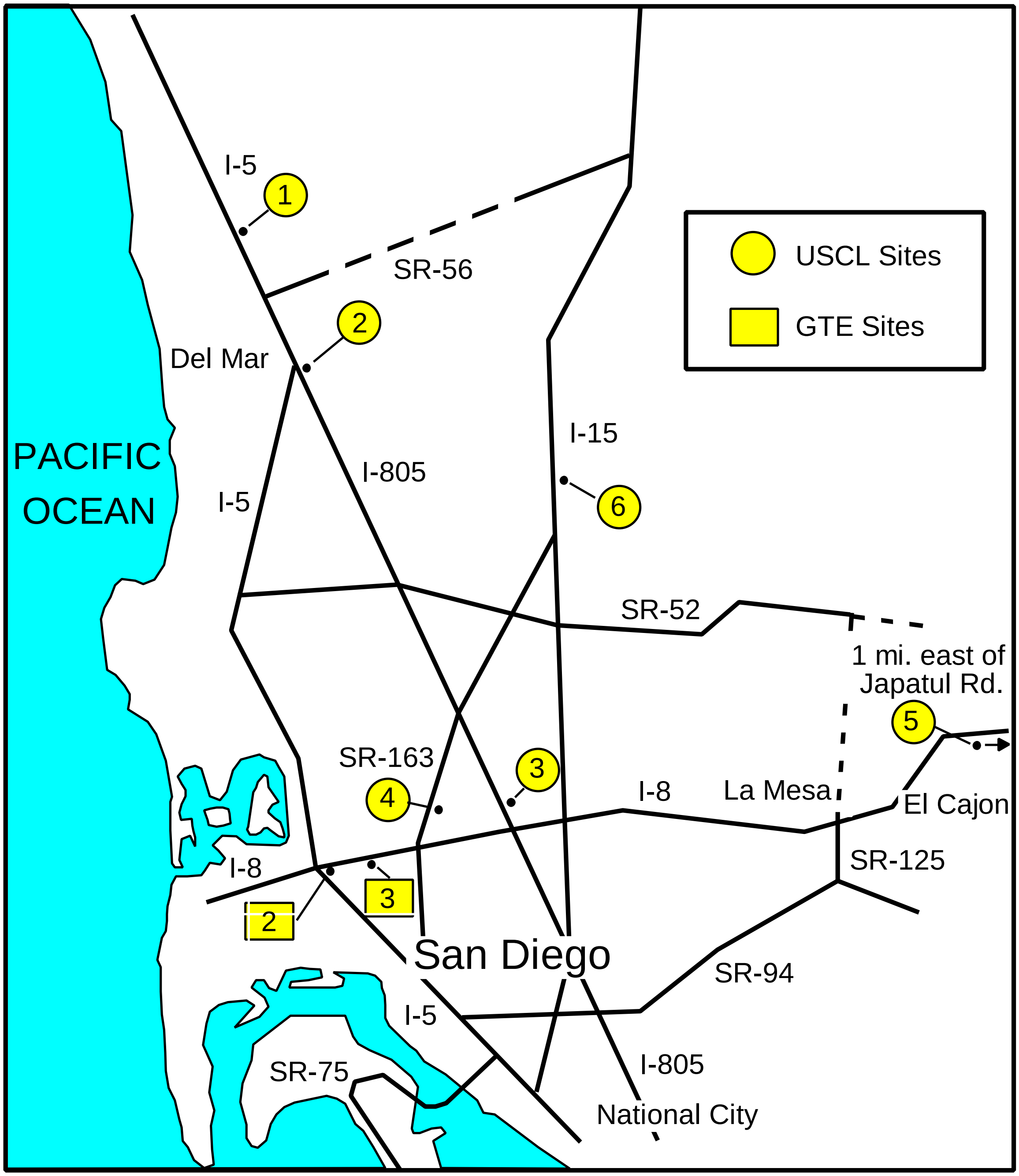
For this subtest, all test systems were required to provide a minimum of one 2-hour window on four consecutive days during which the call box transceiver was in the receive mode. During this time window, the call box could be called from the data collection center (the Project Manager's headquarters) and ordered to download traffic census data. In addition, counters and transmission systems were required to provide data processing, memory, and data format capabilities comparable to those of the baseline system. These requirements are detailed in the subtest system Performance Standards in Appendix D. Actual designs provided either a daily two-hour time window in which the call box could be called (GTE Systems) or ability to contact the call box continuously (U. S. Commlink systems).

SUBTEST CHRONOLOGY

Development of Performance Standards and Specifications

As envisioned in the Evaluation Plan, development of performance standards, specifications, and test system designs were to have been distinct phases in the development of test systems. Performance standards were to have been determined by Caltrans District 11 (as the "customer"). The Project Manager was to refine these into specific functional specifications, which would in turn be used by the vendors to develop detailed specifications and designs.

Figure 2. Map Showing Test System Sites for the Traffic Census Subtest.



In practice, however, there was a great deal of overlap between the development of standards, specifications, and system designs, with formal performance standards being adopted late in the process and continuing to evolve thereafter. In the case of the Traffic Census subtest, the original FOT proposal of October 1992 called for twelve sites. These were to be existing traffic census stations, although additional detectors might be installed in some cases, and new call boxes were to be installed if none were available adjacent to the detectors. Call boxes were to transmit traffic census data on a fixed schedule, with schedule programming to be through the call box maintenance control center. Configuration options were seen as including packaging the counter in the call box or placing it external to the call box with a signal line connecting the counter to the call box microprocessor. Shortly after the FOT was funded, the Work Plan was revised in October 1993 to reduce the proposed number of sites to six.

In the period between October 1993 and July 1994, the RCT discussed a number of issues related to this subtest. Of particular concern were the question of whether internal counters would prove feasible and the problem of connecting call boxes to loops where the loops and call boxes were not immediately adjacent to one another. With regard to the latter issue, it was decided that for purposes of the FOT temporary connections not involving buried conduits would be permitted, although estimates should be made of the costs of trenching, since this would be required for permanent installations.

On July 27, 1994 the initial draft of the project Request for Participation (RFP) was released at a meeting of prospective vendors. This draft RFP called for six traffic census units to be provided. Call boxes were to be connected to existing counters and were to serve as remote terminals to control data extraction. Test systems were to allow for downloading of data to be initiated by either Caltrans or the Project Manager during predetermined time windows. The draft RFP also stated that vendors might include counter functions in the call boxes. After further discussion, language was added to the final RFP of August 15 emphasizing that technologies eliminating or minimizing the use of existing counters or controllers was considered highly desirable by the RCT.

A meeting between the Evaluator and various members of Caltrans District 11 operations staff was held on August 25 to discuss performance standards. The Caltrans staff member in charge of District 11's traffic census program was unable to attend this meeting due to illness. At a meeting with the Evaluator on October 3, this individual made it clear that he was primarily interested in the transmission capability of the call boxes and was not interested in experimenting with different types of counters or in having counters integrated into the call box itself. He emphasized that any counters used in the FOT should be compatible with those currently being used, and expressed concern about the workload implications in the event his staff had to perform maintenance on several different kinds of counters. As a result of these concerns, the Performance Standards contained fairly detailed specifications concerning time bases, data to be transmitted, and data formats to ensure reasonable compatibility with the District's existing counters. The Performance Standards also contained the statement: "It is desirable that counters, detectors, etc., be identical with existing in order to simplify job of Caltrans field crews.

Use of equipment which results in increased training requirements is discouraged." In spite of these concerns, however, the RCT continued to encourage designs which integrated counters into the call box or employed detectors other than standard induction loops.

Development of Test System Designs

Development of designs for the test systems was carried out by the vendors, with the scope of the test, as well as certain design details, subject to negotiation with the RCT. This process began with the vendors' preparation of proposals, which were submitted in late October 1994, and continued into the field test portion of the project. In all cases, the test systems were designed by putting together preexisting components, so that the major design challenge was achieving end-to-end system integration. For the most part, this involved resolving software incompatibilities. Many of these did not surface until after the initial installation of equipment in the field, so that much of the system design actually took place during a fairly extended shakedown period.

GTE Systems

GTE's initial proposal was to provides three units for the Traffic Census subtest. System specifications simply echoed the performance standards and provided little specific information about what was being proposed. In its response to the initial proposals, the RCT asked whether GTE could provide a design which would eliminate the need for a component between the detector and the call box (that is, an internal counter). In its revised proposal of November 22, 1994, GTE stated that it was not practical to incorporate inductive loop detector functions into the currently existing controller board. In this revised proposal, GTE also suggested specific sites, but these were never confirmed by the RCT.

On December 21, face-to-face negotiations were carried out between GTE and the RCT. As a result of these negotiations, GTE was instructed to use a common set of counter units to achieve consistent interface between the call box and the counter. In addition, GTE was asked to provide results of a crash test, since modified call box units were expected to be located in the clear recovery zone of the freeway, and was informed that the RCT would provide a clock source and time zone for recording data. Also, it was confirmed that the GTE maintenance computer (used for the regular call box system in San Diego County) would be used to reset time windows and other controllable parameters of the modified call box.

On January 23, 1995, a working group of the RCT met to recommend cuts in proposed test activities in order to bring them into line with the FOT budget. As a result of this meeting, GTE was instructed to modify its proposal to provide only two units. On February 6, GTE responded by proposing to provide two units, one using a standard external counter and the other incorporating an internal counter. GTE proposed to use these units in all the other subtests as well.

A contract between the RTC and GTE was executed on June 26, 1995. At a TAC meeting on June 28, GTE distributed revised site configurations and a tentative installation schedule. Contrary to what had been proposed on February 6, most sites were now to be used for only one subtest. As before, two traffic census sites were proposed, one using an external counter and one using an internal counter, with one of these to also be used for the Incident Detection subtest. Once again, specific sites were proposed. A meeting between Caltrans and GTE to review the sites was held on July 5; GTE received Caltrans' input at this meeting and issued the final list of sites in early September.

GTE installed equipment for this subtest in mid-September but had considerable difficulty in achieving integration with the data collection system at the Project Manager's headquarters. After redesign of some of the software, equipment at both sites finally became fully functional in late January 1996. Details of this shakedown phase are recorded in a subsequent section of this report.

U. S. Commlink Systems

U. S. Commlink's initial proposal included test sites in both San Diego County and the San Francisco Bay Area. For each area, a single freeway corridor would be instrumented, with multiple use of sites among the subtests. Traffic Census test systems were proposed for four sites in each corridor. Of these four sites, two would use standard Peek external counters, and one each would employ an internal counter and an infrared detector. This proposal also listed detailed specifications for items such as proposed enclosures, poles, bases and foundations, cellular transceivers, controller cards, and power systems. The RCT opposed the use of test sites in the San Francisco Bay Area as being outside the scope of the FOT, but otherwise raised no questions about this subtest in its response to the initial proposals.

In its November 22 reply the RCT's questions U. S. Commlink defended the idea of a Northern California portion of the FOT; however, this was not agreed to by the RCT, and the idea was dropped after the December 21 negotiations. Otherwise, the proposal for this subtest was not modified, except that following the December 21 meeting, the RCT asked that the proposal be increased to include six units, two each employing standard external counters, internal counters, and infrared detectors. Also, following the December 21 meeting, U. S. Commlink was asked to furnish crash test results and informed that the RCT would provide a clock source and zone time for recording data. On January 10, 1995, U. S. Commlink responded to the RCT's summary of the December 21 negotiations by submitting a schematic diagram of its new proposed test configuration. This diagram indicated that A/C power would be required at sites with standard counters and infrared detectors.

Following the meeting of the RCT working group on January 23, 1995 and the subsequent meeting of the full RCT on February 1, U. S. Commlink was instructed to modify its proposal to provide six units. On February 17, U. S. Commlink responded by proposing to provide six units, three using a standard external counter, two using an internal counter, and one using an infrared sensor. U. S. Commlink proposed that each of these units be used in at least one other subtest.

A contract between the RCT and U. S. Commlink was executed on April 6, 1995. At a TAC meeting on May 10, U. S. Commlink distributed a set of "site descriptions" detailing site requirements and equipment to be installed at each site, but did not list specific sites. Following two meetings with personnel from Caltrans, specific sites were designated and presented to the RCT at its June 7 meeting. Subsequent to this, U. S. Commlink announced that it would be modifying the microprocessor card used in its call box units, and that it would be undertaking extensive bench testing of the proposed test systems. On October 20, a demonstration was held at U. S. Commlink headquarters, in which several test system capabilities were demonstrated. These capabilities included transmission of traffic counter data. This demonstration was attended by representatives of the RCT, the Project Manager, and the Evaluator.

Installation of Test System Equipment

The installation phase of the subtest included installation of field equipment and installation of communications and computer equipment at the offices of the Project Manager to collect data. In principle, it also included integration of these two systems to the point that automatically-collected data could be transmitted successfully to the Project Manager's offices; however, there were lingering problems of system integration which extended throughout the test.

Equipment configurations for the Traffic Census subtest are given in the Subtest Description section above. Test system installation sites are shown in Figure 2.

Communications and computer equipment installed at the Project Manager's offices consisted of two suites of equipment, one intended to interface with GTE's field equipment the other to interface with U. S. Commlink's equipment. Purchase and installation of this equipment was timed to coincide with the vendors' installation of field equipment. The first equipment suite, dedicated to the GTE portion of the test, was installed around the beginning of September 1995 and that dedicated to U. S. Commlink around the beginning of October.

Field equipment was installed at the two GTE sites on September 11 and September 12, 1995. At GTE Site 3, however, there were difficulties in connecting with the existing induction loops that were not resolved until around February 1, 1996. The problem in this case was getting Caltrans' permission to use the loops. Meanwhile, there was an ongoing series of malfunctions and system integration problems involving the two units. These included firmware problems, which were first corrected in September; problems in accessing the remote memory units from the GTE maintenance computer, which were corrected in October; a false tilt alarm at Site 3 in October; a corrupted maintenance call scheduling file in the GTE maintenance computer, corrected in late November; and difficulties in downloading files to the computer at the Project manager's headquarters, which were not resolved until January 1996.

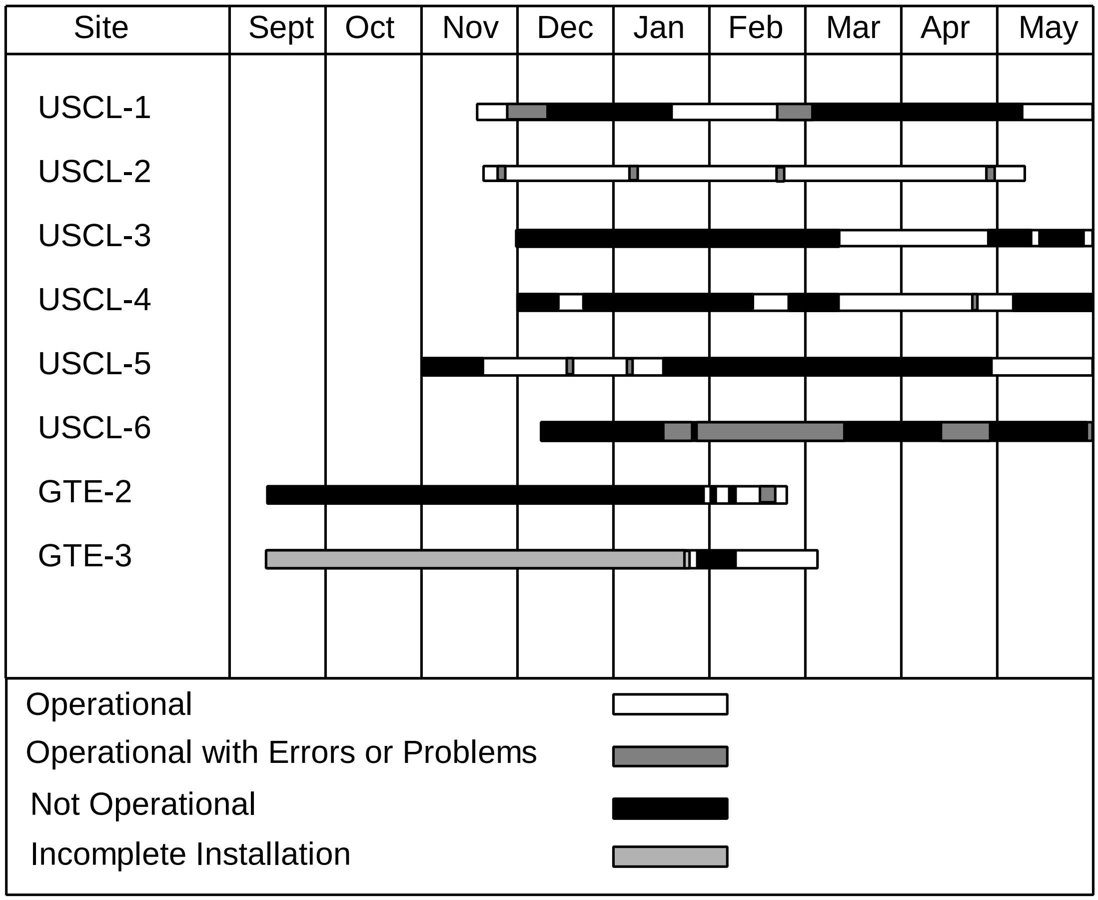
Field equipment was installed at the six U. S. Commlink sites between November 1 and December 6, 1995. Equipment at U. S. Commlink Site 5 was installed November 1; equipment at Sites 1 and 2 was installed on November 17; equipment at Sites 3 and 4 on December 1; and equipment at Site 6 on December 6. All sites except 3 and 6 had functioned successfully by the middle of December, although Site 1 failed shortly after its initial success, and did not come back on-line until the middle of January. The infrared detector at Site 6 did not work properly upon initial installation. The infrared beams were ranging no more than 4 - 5 feet from the detector, which was mounted on an overhead sign. This meant that the only vehicles being detected were large trucks. At the December 14 TAC meeting, the manufacturer was reported to suspect a power supply problem; however, the problem turned out to actually involve a bad ground wire. This particular problem was resolved by the middle of January, but there were continuing problems with the functioning of the sensor, which are discussed in the following section. At Site 3, there were at least two problems involving wiring. First, in December, a cable was eaten through by rodents, and had to be repaired; later, it was discovered that a contractor had cut the power supply cable to this site, which required external power to operate the traffic counter. This site did not function properly until March 11, 1996.

Conduct of Subtest

It had initially been expected that field equipment would be functional after a brief shakedown period, and that the bulk of the time in the data-collection portion of the FOT would be spent in determining the reliability and operating costs of the various test systems. As it turned out, however, there were serious problems with system integration and possibly with the basic functioning of some of the counters used in the test, so that the main portion of the subtest was actually an extended shakedown period. Figure 3 shows the periods during which the various traffic census test sites were operational. As can be seen from the chart, only U. S. Commlink Site 2 was consistently functional.

In the case of the GTE systems, delays in establishing functional systems led eventually to a threat to suspend the test. At the January 4, 1996 meeting of the RCT, concern was expressed that the FOT was seriously behind schedule. Particular concerns included the failure of the GTE traffic census units to provide successful transmissions to the data collection point, the failure of U. S. Commlink's infrared sensor unit at Site 6 to function properly, and lack of progress by U. S. Commlink in getting its weather stations operational for the Hazardous Weather Reporting subtest. As a result of these concerns, the RCT refused to fully fund vouchers that GTE had submitted, on the grounds that the traffic census units were not completely operational, and decided to have San Diego SAFE send both vendors notices to cure default.

Figure 3. Operational Status of Traffic Census Sites.



These notices were distributed at the January 11 TAC meeting, along with a schedule revision establishing "firm" dates by which data collection was to begin for each subtest. In the case of the Subphase 1 subtests (Traffic Census and Hazardous Weather Reporting) the deadline was January 26. By the time the notices were distributed, however, GTE had managed to demonstrate successful functioning of the unit at Site 2, although the site was not consistently operational until the near the end of January. At Site 3, GTE had problems securing Caltrans permission to use the inductance loops, and was not able to complete installation until early February. Both GTE sites were converted from Traffic Census to Incident Detection around the beginning of March, and at this time the counters used for the Traffic Census subtest were replaced.

Following replacement of the counters, GTE Sites 2 and 3 were redesignated as Sites 13 and 14. These sites (and the other GTE incident Detection sites) were supposed to have the capability of being contacted during predetermined time windows to download traffic data. The Project manager, however, was unable to establish contact reliably. Finally it was determined that the GTE maintenance computer was changing the time windows in an unpredictable fashion. This problem had not been corrected by the time data collection was suspended at the end of May.

With the exception of Site 3, all U. S. Commlink sites involving loop detectors had been contacted successfully by the Project Manager by the middle of December. T-Cubed reported, however, that it was not always possible to download and save data because the field units were purging data files each time they were contacted, so that if a second contact were made, the previously downloaded data would be missing. It is not clear when this problem was resolved. Meanwhile, all U. S. Commlink units other than Site 2 experienced repeated failures of one sort or another. These failures included software problems, problems with external power supplies at Sites 3 and 4 (cables eaten by rodents, cables cut by Caltrans contractors, and a main power switch left in the off position inadvertently), failure of the cellular phone and the counter at Site 5, and possibly other component failures.

At Site 6, there were continuing problems with the infrared detector. As previously described, there were obvious malfunctions in the detector when it was first installed, and by the beginning of January, the RCT was considering suspending this portion of the subtest. The unit was reactivated in mid-January before the deadline established by the cure notice, but there were continuing problems with inaccurate counts and loss of contact with the site. At the end of April the site was temporarily shut down so that the manufacturer could install new software. This upgrade, which was expected to solve reflectivity problems that had been experienced by the detector, was completed on May 21, and the unit was operational at the end of the month. Even at this point the counts were not consistently accurate, however.

Data collected for the Traffic Census subtest included traffic data files created by the counters and data provided by Caltrans that were used for purposes of comparison. Data supplied by Caltrans included traffic census data and data from nearby location of the San Diego ramp metering system. Data from the test systems were collected throughout the period in which they were operational. Data were analyzed by reviewing counts from the test systems for reasonableness and consistency and, where possible, comparing them with the Caltrans counts.

ANALYSIS OF TEST SYSTEM EFFECTIVENESS

System Adequacy

The adequacy of the various test system designs was determined by comparing the final designs with performance standards established by the RCT and published in the FOT Evaluation Plan. Also, test system designs were reviewed for conformity to any other specifications established by the Project Manager in the Request for Participation (RFP) or promised by the vendors in their responses. Finally, wherever possible, the accuracy of the counts was checked by comparing them with data from other sources such as the Caltrans traffic census program or the San Diego ramp metering system. Appendix E presents detailed comparisons of actual designs with performance standards and specifications related to the basic functionality of the test systems.

In general, test system designs based on loop detectors met or exceeded performance standards and specifications, even though some of the performance standards had been intended to limit the choice of traffic counters. A major exception was the failure of the GTE systems to provide the specified time windows for downloading data. Also, the systems supplied by U. S. Commlink did not provide the specified data format for traffic counts; in this case, however, the test system actually provided more flexibility in formatting data files than was required. Otherwise, all loop detector system designs met or exceeded all standards and specifications except those that stated directly that "it is desirable that counters, detectors, etc. be identical with existing..." or the conflicting specification from the RFP that "technologies which would eliminate or minimize the use of existing counters/detectors are highly desirable."

Actual counts were verified for U. S. Commlink Site 2 and found to agree closely with counts from the Caltrans traffic census program. At other sites, it proved impossible to make direct comparisons because comparable data was not available on the same dates; in part, this was due to the intermittent operation of the test systems. Counts at all sites did appear to be reasonable, however.

The design of the infrared detector system installed at U. S. Commlink Site 6, on the other hand, did not meet the performance standards in several areas. These included: 1) it was limited to counting a single lane, as opposed to up to 12, as called for by the standards; 2) it lacked the capability to store counts for long periods of time (a rotating 24-hour memory as opposed to the standard that systems were to be able to store up to 40 days worth of hourly counts); 3) there were minor discrepancies in terms of the time intervals available for aggregating counts; and 4) it was capable of a maximum individual transmission of 2,048 records as opposed to 6,000 records, as called for by the standards.

In order to be useful for routine traffic census activities as presently carried out by Caltrans, it is necessary that systems be able to count multiple lanes and that they be able to be polled at intervals of up to one month. The FOT did not actually demonstrate that more than one infrared detector (counting one lane) can be integrated with a single call box, although the call boxes are designed to provide for connections to up to four external devices, all of which could presumably be infrared detectors. Finally, the limitation of the system to counting a single lane per detector has important cost implications. Consequently, this test did not establish that the infrared sensor based system is adequate for typical use in the traffic census program. Rather, it is more likely to be useful where accurate vehicle classification is a major issue.

It was not possible to directly verify counts produced by the infrared unit because comparable data were not available. Caltrans traffic census data were available at this site, but were aggregated over all lanes. These counts were compared with those produced by the smart call box system immediately after the last firmware revision in late May. It was possible to verify that peaking patterns for the counts produced by the infrared device were similar to those for the freeway as a whole for some days, but the times recorded in the smart call box count files were clearly in error on most days, and counts appeared to become erratic after a day or two. Meanwhile, speeds recorded in these data sets were obviously in error. From this, it may be concluded that this site never produced accurate data.

System Reliability

Evaluation of system reliability was a major goal of the FOT as originally planned. Indicators of system reliability were expected to include overall system availability, transmission reliability, and transmission delay. Although there were no specific reliability standards set for the traffic census subtest, the Evaluation Plan stated that availability and transmission reliability rates of around 90 per cent would be required.

As discussed in a previous section (see “Conduct of Subtest” under “Test System Chronology”), the traffic census test systems experienced major problems with transmission reliability and system availability at all but one site (see Figure 3). Although it is difficult to establish the exact availability rates for this subtest, since contact between the data collection point and the field units was not continuous, it is clear that the availability rate exceeded 90 per cent only at U. S. Commlink Site 2. Transmission delay, on the other hand, did not appear to be a problem.

For the most part, the low rates of system availability reflect the fact that system integration turned out to be the key technical issue in the FOT. Contrary to what had been expected initially, the various test systems were not well-developed by the time equipment was installed in the field. Consequently, what was observed during the FOT was not “normal” system operation, but rather an extended shakedown period during which design flaws (especially in communications software) were discovered and corrected. For this reason, the data collected as a part of the FOT do not constitute an accurate basis for predicting how large-scale smart call box systems will perform once they are fully developed. On the other hand, the FOT definitely failed to demonstrate that the systems tested *are* reliable in their current state of development.

It should also be understood that system availability was adversely affected not only by the number of problems experienced but also by sometimes excessive amounts of time involved in correcting them. There were a number of reasons for these delays, some of which were the result of particular circumstances surrounding the FOT. These included: 1) Neither vendor was locally-based (although GTE might be considered almost local), and neither had assigned a large engineering staff to the project. As a result, vendors tended to delay responses to system failures until their next scheduled visit. Once efforts were under way to fix problems, system repairs had to compete with other FOT activities for staff time. 2) Because the test systems were new, it sometimes took extended periods of time to diagnose the problems. 3) Because the test systems were experimental, some of their components were prototypes. This precluded simply replacing components that were malfunctioning in an attempt to get the system back in operation immediately.

If it is assumed that the initial system design problems will be resolved eventually, smart call box systems are potentially as reliable as the baseline system. Caltrans does not keep detailed records of the availability of its conventional traffic census units, but this is described as being “adequate.” Since the traffic counters are similar to those currently used, the main difference in reliability should lie in the communications system. Review of records for the San Diego voice call box system for the period January 1 - May 15, 1996 established that system availability, under the worst-case scenario for repair times, is around 99.7 per cent. Consequently, there is certainly potential for smart call box systems to equal hardwire systems in terms of reliability. In order for this potential to be realized, however, it will be necessary to resolve all system integration problems.

COMPARISON OF TEST AND BASELINE SYSTEMS

System Adequacy

The loop-detector-based smart call box systems involved in this field test are essentially the same as hard-wire telephone systems in terms of basic functionality. The only real exception is that the GTE systems did not provide the ability to poll the counters at any time, but this feature is not considered essential for traffic census purposes. The infrared-sensor-based system tested by U. S. Commlink, on the other hand, failed to provide several functions that are important to traffic census programs. These include the inability of the field unit to store data for more than 24 hours and the lack of evidence that the system can count more than a single lane. It may be possible to integrate more than one infrared sensor with a single call box, but this was not demonstrated in this FOT. Also, it may be possible to devise a system to automatically poll this system on a daily basis and store the counts elsewhere; however, this is less convenient than use of the field data storage capabilities provided by existing loop counters. In addition, this system never produced accurate data on a consistent basis.

System Reliability

In their current state of development, the test systems do not compare favorably with the baseline system in terms of reliability. In the long run, smart call box systems appear to have the potential to equal or exceed the reliability of the baseline system; however, this potential will be realized only after initial system design flaws have been identified and eliminated.

ANALYSIS OF TEST AND BASELINE SYSTEM COSTS

Test system costs include capital costs, maintenance costs, and the cost of cellular airtime. Baseline system costs include capital costs, maintenance costs, and telephone connection charges.

Capital Costs

Capital costs were determined by having representatives of Caltrans District 11 structure bids for the installation of test and baseline systems at the sites actually used, and then asking the vendors what they would bid for these items as a part of a full-scale deployment. For items not supplied by the vendors, standard Caltrans cost estimates were used. Capital cost estimates for sites involved in the Traffic Census Subtest are detailed in Appendix F. Note that for installations intended to serve more than one function, these cost estimates include some items that were not related to this subtest.

Capital cost comparisons are summarized in Table 1.

Table 1. Capital Cost Comparisons for Traffic Census Sites.

	Costs		Difference,
Site	Test System	Baseline System	Baseline - Test
USCL-1	$44,130	$77,480	$33,350
USCL-2	$57,800	$67,500	$9,700
USCL-3	$23,060	$29,000	$5,940
USCL-4	$26,850	$28,300	$1,450
USCL-5	$7,815	$110,915	$103,100
USCL-6	$75,920	$156,620	$80,700
GTE-2	$10,710	$22,790	$12,080
GTE-3	$7,230	$14,595	$7,365

It may be seen from the table that, although capital costs are highly site-specific, the test system involves a large advantage in capital cost at most sites. This is primarily due to the high cost of trenching and installing telephone cables. In general, hardwire telephone infrastructure was not available in the immediate vicinity of these sites, even where A/C power was available. Under current Caltrans policy, moreover, any extensions of telephone lines must be routed through public right-of-way, which substantially increases access distance in some cases.

Note also, in comparing costs at the U. S. Commlink sites, that the Schwartz infrared traffic sensor costs $6,500 for an installation that can cover a single lane. Loop detector installations cost from $1,100 to $3,300 for the counter plus $850 per loop, including the cost of installation and the lane closures required for installation. This means that loop detectors are substantially cheaper, especially where large numbers of lanes are to be counted.

Table 1 lists the total capital costs for the sites in question. Some of the equipment at the U. S. Commlink sites was not necessary for this subtest. Also, costs at most of the U. S. Commlink sites were heavily influenced by the cost of providing A/C power, and costs at all loop-detector sites were influenced by detector installation costs. Both external power costs and loop installation costs vary widely depending on the characteristics of the site. To give an idea of what smart call box traffic census systems might cost by themselves, and the impact of the cost of external power supply and loop installation costs, Table 2 lists site costs including only traffic census equipment, the cost of external power supply and loop installation, and traffic census costs exclusive of power costs and loop installation costs.

Table 2. Site Costs for Traffic Census Alone.

Site	Cost, Traffic Census Only	External Power and Loop Costs	Cost, Exclusive of External Power and Loops
USCL-1	$38,330	$27,800	$10,530
USCL-2	$50,200	$40,400	$9,800
USCL-3	$23,060	$17,200	$5,860
USCL-4	$25,350	$16,650	$8,700
USCL-5	$7,600	$1,700	$5,900
USCL-6	$75,920	$58,220	$17,700
GTE-2	$10,710	$7,100	$3,610
GTE-3	$7,230	$3,400	$3,830

Operating Costs

Operating costs include telephone charges and maintenance costs. Current telephone charges paid by Caltrans for conventional telephone service and San Diego SAFE for cellular service are $14.00 per month per line for conventional service and $10.00 per month per line for cellular service. This means that the test systems actually have a slight advantage in terms of telephone charges in the San Diego area, although this may not be true elsewhere.

Although determination of maintenance costs for smart call box systems was a major goal of the FOT evaluation as initially conceived, the data collected are not adequate for this purpose. This is due to the fact that initial design flaws dominated test system reliability problems. Also, it should be recognized that maintenance costs may depend heavily on certain institutional decisions, particularly that of whether maintenance is to be done by vendors under contract or in-house by public agencies.

Life-Cycle Costs

Since capital costs vary widely depending on site conditions (particularly access distances to hardwire telephone systems) and maintenance costs for the test systems are uncertain, it is not possible to determine exact life cycle costs for the test systems or to compare them with those of the baseline system. A more reasonable approach is to determine the break-even points between the test and baseline systems, based on telephone access distances, differences in maintenance costs, and differences in assumptions about interest rates. The tables below give the maximum additional maintenance cost per unit for the smart call box system at break-even, as a function of the access distance for conventional telephone and the assumed interest rate.

Table 3 gives break-even maintenance costs for systems with internal counters and Table 4 those for systems with external counters. The difference between these two designs is the cost of the additional cabinet housing the external counter. All calculations are based on an assumed life of 10 years with no salvage value, and the monthly telephone charges listed in the section on "Operating Costs." In addition, all calculations assume that for the baseline system both trenching and cabling is required for the full access distance listed, but that there are no additional costs in providing hardwire connections, such as jacking conduits under traffic lanes. Trenching costs are assumed to be $10.00 per foot, and cabling costs to be an additional $1.00 per foot, for a total of $11.00 per foot; these cost assumptions are based on estimates by Caltrans.

Table 3. Break-Even Maintenance Cost Differences for Smart Call Boxes with Internal Counters.

Access Distance for	Max. Difference in Annual Maintenance Costs (Call Box - Baseline) for Given Interest Rate		
Baseline System, Ft.	5%	7.5%	10%
100	$333	$369	$406
200	$475	$529	$585
500	$903	$1,010	$1,122
1,000	$1,615	$1,811	$2,018
2,000	$3,039	$3,414	$3,809
5,000	$7,313	$8,222	$9,181
10,000	$14,435	$16,235	$18,135

Table 4. Break-Even Maintenance Cost Differences for Smart Call Boxes with External Counters.

Access Distance for Baseline System, Ft.	Max. Difference in Annual Maintenance Costs (Call Box - Baseline) for Given Interest Rate		
	5%	7.5%	10%
100	- $120	- $141	- $164
200	$22	$19	$15
500	$449	$500	$553
1,000	$1,162	$1,301	$1,448
2,000	$2,586	$2,904	$3,239
5,000	$6,860	$7,712	$8,611
10,000	$13,982	$15,725	$17,565

For the sites involved in this subtest, telephone access distances varied from 115 ft to 8,500 ft, with the median distance being around 800 ft. Thus for sites typical of the subtest, smart call box systems are likely to have a cost advantage over conventional systems so long as the difference in maintenance costs does not exceed $1,000 for installations with external counters or $1,500 for those with internal counters.

CONCLUSIONS

This section of this report documents the evaluation of the Traffic Census Subtest of the Smart Call Box FOT. Objectives of the evaluation were to determine the cost-effectiveness of using smart call boxes for the processing and transmission of traffic census data. This included assessing the effectiveness of the various test systems, estimating life cycle costs, and identifying tradeoffs among the baseline system and the various test systems. In addition, the subtest evaluation addressed issues such as potential improvements to the designs tested in the FOT and actions related to specific test systems that should be undertaken prior to deployment. A more general discussion of actions required before deployment may be found in the subtest report on Institutional Issues. Major conclusions include:

1. All loop-based systems tested in this FOT appear to be adequate in terms of their basic functionality, although it was not possible to verify the accuracy of the counts at most locations. In the case of the GTE systems, however, failure to provide the specified time windows for downloading data is a serious problem. In the case of the U. S. Commlink loop-based systems, the continuous availability of the system for downloading is a major advantage.

2. The functionality of the infrared-detector-based system was inadequate. The limitation of this system to a single lane per counter and the 24-hour rotating memory feature are major deficiencies. Also, the counts were not consistently accurate; at best, these detector systems require careful adjustment in order to function correctly.

3. System reliability, as measured by system availability, was poor for all systems tested. It is believed that this problem can eventually be corrected, since many of the failures were due to initial design flaws. Also, the amount of down time experienced during the FOT was due in part to conditions peculiar to the FOT. Nevertheless, further testing will be required to establish the reliability of these systems and to estimate their maintenance costs.

4. Capital costs of the systems tested are expected to vary widely depending on the type of system, the cost of supplying external A/C power where that is required, and the cost of providing detectors. Overall costs of the GTE systems were on the order of \$7,000 to \$10,000, or \$3,500 to \$4,000 exclusive of loop installation costs. The overall cost of the U. S. Commlink external-counter systems ranged from \$23,000 to \$50,000, most of which was due to the cost of supplying A/C power to the test sites; costs for this system range from \$6,000 to \$10,500 exclusive of external power supply and loop installation costs. The U. S. Commlink internal-counter system cost about \$7,500, or about \$6,000 exclusive of loop installation costs. The U. S. Commlink infrared detector system cost about \$76,000, or about \$17,700 exclusive of power supply costs. Costs for U. S. Commlink systems consider only those components installed at each site that were used for processing and transmission of traffic census data.

5. For most sites, use of infrared detectors is significantly more expensive that use of loop detectors. This is due both to the high cost per unit for the detector-counter unit and to the fact that these detectors cover only one lane apiece.

6. The cost-effectiveness of the various test systems, when compared with the baseline system, depends on access distances to the hardwire telephone system and maintenance costs for the smart call box systems. Since maintenance costs for the test systems could not be determined, these break-even points between the test systems and the baseline system may be stated in terms of differences in maintenance cost. For telephone access distances typical of the FOT, break-even annual maintenance cost differences are on the order of \$1,000 to \$1,500 per unit.

7. In cost-effectiveness comparisons among the test systems themselves, loop-detector based systems will generally be more cost-effective than infrared-detector-based systems. Among the loop-based systems, those not requiring external power are more cost-effective than those that do, provided reliability and maintenance costs prove to be similar.

8. Continued testing of the systems involved in this subtest to establish reliability and maintenance costs should be undertaken prior to deployment. Also, if the infrared detector system is to be used for traffic census purposes, the memory features of the Schwartz detector need to be redesigned to allow storage of data for considerably more than 24 hours. Given the way the existing Caltrans traffic census program operates, memory capacity for about 30 to 40 days of data is desirable.

9. Design enhancements that would improve the utility of the test systems include modification of the GTE systems to provide continuous availability for downloading data, and successful combination of traffic census and low speed alarm capabilities in a single counter. U. S. Commlink was successful in providing continuous availability for its systems. Both vendors attempted unsuccessfully to provide both traffic census and alarm capability with a single device. In the case of the GTE system, the counter was said to have possessed this capability, but system integration failures apparently prevented alarms from being relayed to the data collection point (see subtest report on Incident Detection).

The subtest also provided several important lessons related to technology, system design concepts, the design process, and the process of testing and evaluating the systems. These included:

1. Infrared sensor technology is expensive, and these devices appear to still be in the experimental stage. The model tested here may need further development in order to be reliable. Also, given its memory capabilities, the Schwartz device is not well-suited to traffic census use.

2. System integration was a major design issue for the systems involved in this subtest. Some consequences were 1) More time should have been allowed for design. Just because all the components are "off-the-shelf" does not mean that they will work well together. Identifying and correcting the resulting software problems is very time consuming. 2) It is unrealistic to expect that the components will truly be "off-the-shelf," even if a satisfactory product already exists. Traffic counter manufacturers, in particular, introduce improved products from time to time and naturally want to use the latest version when new systems are developed. "Upgrades" tended to result in software incompatibilities with equipment that had been compatible with the previous version. 3) A standard communications protocol for traffic counters and similar devices that recognizes the requirements of wireless communications systems is highly desirable. Given the tendency for counter equipment to evolve, such a standard may be the only way to ensure that smart call box systems will not need to be reinvented every time a new model of counter is introduced. It is questionable, however, whether the market for smart call box systems is large enough to support development of such a protocol. Any such protocol would form part of the National Transportation Communications for ITS Protocol (NTCIP) standards currently under development (*2*). In order to provide standards specifically adapted to smart call boxes, the current

NTCIP effort will need to be extended to include standards for smart call box higher level interactions.

3. Most of the data processing for the systems involved in this subtest took place in the counters, with the call boxes serving primarily as a data communications link. Use of a cellular modem without a microprocessor card is a possible alternative to the designs tested here. This system design might also have avoided some of the system integration problems, since it would have been more compatible with existing traffic counter designs.

4. Where the choice is between use of a stand-alone device with a dedicated cellular phone (whether a smart call box or some other design) and a multipurpose smart call box (that is, one providing both voice and data transmission) the decision may depend on the distance from the detectors to the call box. Where an installation is planned for smart call box use from the start, detectors can be installed in close proximity to the call box (or vice versa), but for installations where both call boxes and loops already exist, distances may be prohibitive.

5. The evaluation objectives of this subtest were based on the false assumption that system functionality would not be a major problem. In retrospect, the subtest evaluation should have focused on system functionality. Evaluation of reliability and maintenance requirements requires a much longer test, and should not have been undertaken until after basic functionality was well-established.

INCIDENT DETECTION SUBTEST

SUBTEST OBJECTIVES

The objective of this subtest was to evaluate the cost-effectiveness of smart call boxes for processing and transmitting incident alarms. In the course of planning for the subtest, it was decided to limit the test to detection of traffic congestion, as indicated by specified speed thresholds, rather than to try to distinguish recurrent congestion from incident congestion. The evaluation included determining the following:

- The relative effectiveness of several different test systems involving smart call boxes for processing and transmitting congestion alarms when compared with one another and with a baseline system consisting of loop detectors and Model 170 controllers. Baseline controllers are used by the San Diego ramp metering system and are connected by hard-wire telephone lines to computers at the San Diego Transportation Management Center (TMC). Data from the baseline system is used to create color-coded displays showing speeds at numerous locations on the freeway system. Effectiveness was defined to include the functional adequacy, accuracy, and reliability of the data processing and data transmission provided.

- The projected life-cycle costs of different test systems involving use of smart call boxes to process and transmit congestion alarms, as compared to one another and to the baseline system.

- Tradeoffs (if any) between use of the various smart call box systems and hard-wire telephone systems for the processing and transmission of congestion alarms.

SUBTEST DESCRIPTION

Eight smart call box units were tested. These included three different test system configurations developed by two separate vendor teams. The vendor team headed by GTE designed and installed six units involving loop counters installed in the call box cabinet (internal counters). The other vendor team, headed by U. S. Commlink, designed and installed two units. One of these employed a loop counter external to the call box and the other an infrared detector. Two of the GTE units used in this subtest were also used in the Traffic Census subtest. Both U. S. Commlink units were also used in the Traffic Census subtest, and one was also used in the CCTV Surveillance subtest. Appendix B documents overall system configurations for the two vendor teams, showing the units used in each subtest.

All test systems for this subtest involved field units consisting of traffic counters and call boxes that reported to a data collection center at the Project Manager's headquarters. All test systems integrated call boxes with existing traffic counting devices. With the exception of the infrared counter, these were loop counters. In all but one case, a major part of the information processing capability of the system resided in the counter, rather than in the call box. In these cases, counters interpreted analog signals from sensors, determined average speeds, and processed counts to determine whether alarm thresholds had been crossed. Call boxes were used primarily as communications devices, transmitting alarms and downloading data in response to prompts from the data collection center. In one case, the call box microprocessor was used to prompt data bursts from the counter and evaluate current speed to determine whether speed thresholds had been crossed.

The following is a detailed description of the sites and equipment included in each test system. Block diagrams showing the functioning of these systems are documented in Appendix C.

GTE Systems

- ***System Configuration: Internal Loop Detector Counter***

  Equipment:

  1 - GTE Call Box
  1 - Solar Charging Assembly
  1 - Diamond Traffic Phoenix Counter

  Sites:

  - I-8, Post Mile Number 0.214, Call Box Number 8-027, Rosecrans On-Ramp. GTE Site # 13.
  - I-8, Post Mile Number 1.450, Call Box Number 8-16, Taylor St. - Hotel Circle. GTE Site # 14.
  - I-805, Post Mile NB 17.380, Call Box Number 805-174, NB to I-8, GTE Site #7.
  - I-805, Post Mile NB 25.300, Call Box 805-254, La Jolla Village Dr. GTE Site #21.
  - I-805, Post Mile NB 26.430, Call Box Number 805-264, Mira Mesa Blvd. GTE Site #22.
  - I-805, Post Mile NB 20.888, Call Box Number 805-210T, Connector from SR-163. GTE Site #23.

U. S. Commlink Systems

- ***System Configuration 1: External Loop Detector Counter***

  Equipment:

  1 - U. S. Commlink, Smart Card System
  1 - Peek, SOH Counter
  1 - Cubic Call Box Assembly
  1 - Call Box Mounting Assembly
  1- Solar Charging System

  Site:

  - I-5/I-805, Post Mile NB 805 28.526, Call Box Number 805-288, at I-5/I-805 Interchange. U. S. Commlink Site # 2.

- ***System Configuration 2: Infrared Sensor Counter***

  Equipment:

  1 - U. S. Commlink, Smart Card System
  1 - Schwartz Electro-Optics, Autosense Laser Sensor System
  1 - Cubic Call Box Assembly
  1 - Call Box Mounting Assembly
  1 - Solar Charging System

  Site:

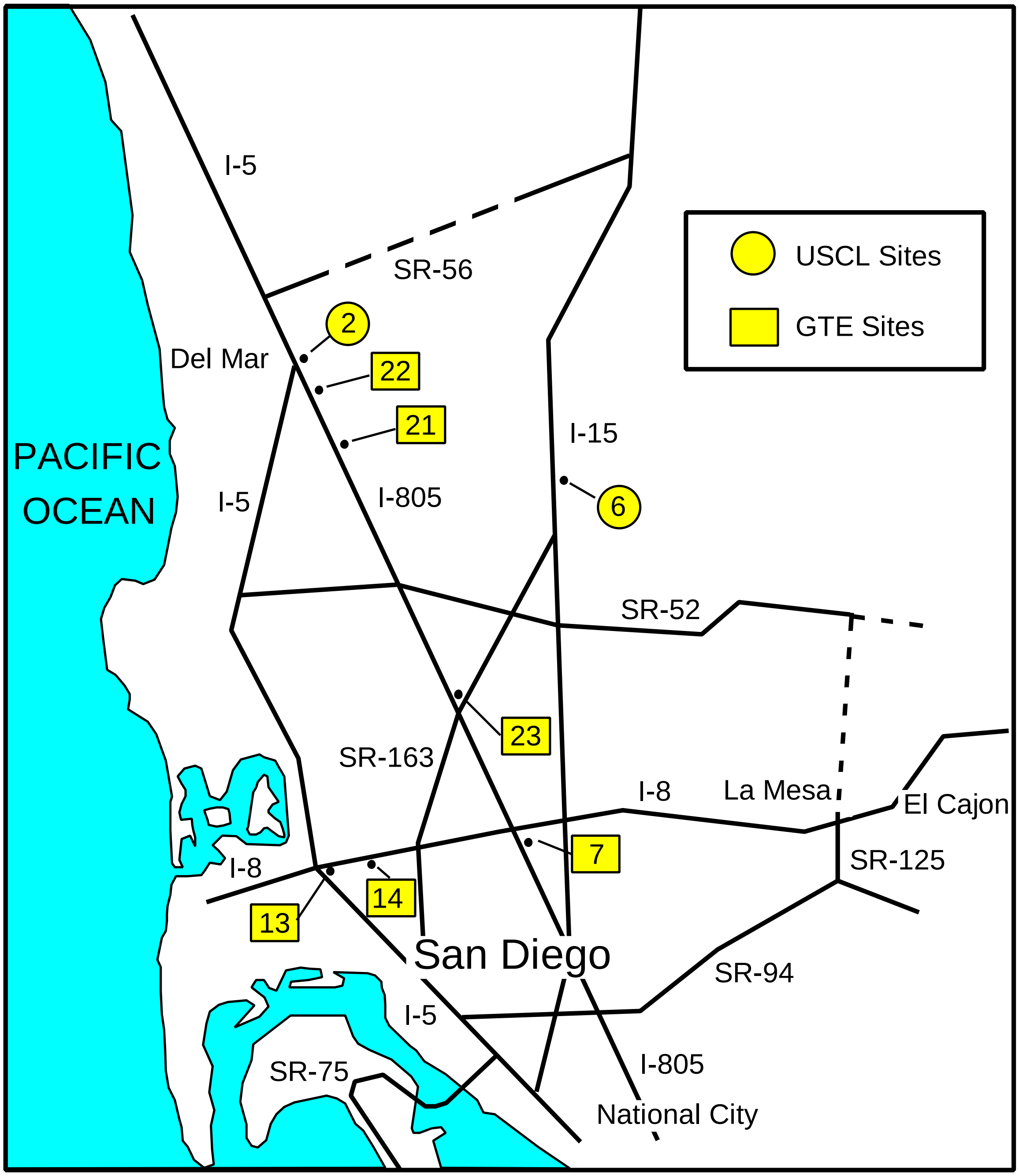
  - I-15, Post Mile NB 12.957, Call Box Number 15-124, Ammo Rd. U. S. Commlink Site # 6.

Figure 4 is a map showing the location of these sites.

Data Transmission and Processing Tasks

For this subtest, all test systems were required to determine volumes, occupancies, and speeds from detectors on a continuing basis. They were further required to continuously execute an algorithm that would respond to threshold speeds of 50 MPH and 40 MPH, and to transmit alarms whenever these thresholds were crossed. These requirements are detailed in the subtest system Performance Standards in Appendix D.

Figure 4. Map Showing Test System Sites for the Incident Detection Subtest.



SUBTEST CHRONOLOGY

Development of Performance Standards and Specifications

As envisioned in the Evaluation Plan, development of performance standards, specifications, and test system designs were to have been distinct phases in the development of test systems. Performance standards were to have been determined by Caltrans District 11 (as the “customer”). The Project Manager was to refine these into specific functional specifications, which would in turn be used by the vendors to develop detailed specifications and designs.

In practice, however, there was a great deal of overlap between the development of standards, specifications, and system designs, with formal performance standards being adopted late in the process and continuing to evolve thereafter.

In the case of the Incident Detection subtest, the original FOT proposal of October 1992 called for twenty sites, fifteen in urban areas and five in rural areas. These were envisioned as being located contiguous to one another. When threshold boundaries for as yet unspecified traffic parameters were crossed, the call box would transmit an alarm to the TMC. In urban areas, the TMC workstation would compare traffic conditions for adjacent call boxes to determine the presence of an incident. For rural areas, any major perturbation in the traffic flow might be considered an incident. The call box was to transmit sensor data in response to the preprogrammed alarm status; communications from the control center to the call box would include commands to set threshold parameters and reporting times. Physical configuration options included packaging the counter mechanism in the call box or placing the counter external to the call box with a signal line connecting the counter to the call box microprocessor. The major communications issue in this subtest was seen as being the ability of the call boxes to remain in the receive mode for operationally useful intervals of time to allow polling from the TMC. In October 1993, shortly after the FOT was funded, the Work Plan was revised. The description of the Incident Detection subtest was unchanged in this revision, despite the fact that it reduced the numbers of sites for all the other subtests.

In the period between October 1993 and July 1994, the RCT discussed a number of issues related to this subtest. One issue (which also applied to the Traffic Census subtest) was whether internal counters would prove feasible. A second was the problem of connecting call boxes to loops where the loops and call boxes were not immediately adjacent to one another. With regard to the latter issue, it was decided that for purposes of the FOT temporary connections not involving buried conduits would be permitted, although estimates should be made of the costs of trenching, since this would be required for permanent installations. Other questions related to the choice of incident detection algorithms. These included the question of whether any existing algorithm was really suitable. Published reports (*3-5*) indicated that, at best, detection rates were on the order of 70 per cent; also, all existing algorithms were believed to require fairly extensive calibration. With regard to the calibration issue, it was not clear whether call boxes could transmit sufficient data to permit calibration, even if they were successful in detecting alarm conditions once data thresholds were established.

On July 27, 1994 the initial draft of the project Request for Participation (RFP) was released at a meeting of prospective vendors. This draft RFP called for twenty incident detection units to be provided. Call boxes were to be connected to existing counters and were required to detect flow parameter thresholds and initiate calls when thresholds were reached. In contrast to the original proposal, there was no suggestion that actual traffic data were to be transmitted or that any data processing would take place at the TMC; rather, test systems were required only to determine and transmit alarms. Prospective vendors were instructed that the RCT would provide incident detection algorithms, since no decision had yet been made about which algorithm or algorithms to use. The RFP also stated that call boxes were to be linked to changeable message signs (CMSs) used in Subtest 4, and that they must be capable of being remotely programmed to adjust incident detection parameters. After further discussion, language was added to the final RFP of August 15 emphasizing that technologies eliminating or minimizing the use of existing counters or controllers were considered highly desirable by the RCT.

A meeting between the Evaluator and various members of Caltrans District 11 operations staff was held on August 25 to discuss performance standards. At this meeting, representatives of the Caltrans TMC stated that the baseline system actually provided only congestion detection, and that they were not interested in having the test system go beyond this. In the case of the baseline system, speed estimates are calculated from traffic volumes and occupancies. Three speed categories are recognized: more than 50 MPH, 40 MPH - 50 MPH, and less than 40 MPH. Each of these speed categories is represented by a different color in a computer-generated display of the freeway system, and TMC personnel make judgments as to whether an unusual speed condition might represent an incident. It was decided that the Performance Standards should require only that the test system be able to transmit an alarm whenever 50 MPH or 40 MPH speed thresholds were crossed, since this would provide capabilities comparable to those of the baseline system. In addition, the Performance Standards provided detailed descriptions of data to be transmitted and established system reliability criteria. The Performance Standards had an important effect on the design of the test systems for this subtest, since the RCT thereafter dropped all references to use of algorithms intended to distinguish incident congestion from recurrent congestion.

Development of Test System Designs

Development of designs for the test systems was carried out by the vendors, with the scope of the test, as well as certain design details, subject to negotiation with the RCT. This process began with the vendors' preparation of proposals, which were submitted in late October 1994, and continued into field test portion of the project. In all cases, the test systems were designed by assembling preexisting components, so that the major design challenge was achieving end-to-end system integration. For the most part, this involved resolving major software incompatibilities. Many of these did not surface until after the initial installation of equipment in the field. In the case of the Incident Detection subtest, the field test phase was so short that these problems were never corrected.

GTE Systems

GTE's initial proposal was to provide ten units for the Incident Detection subtest. Call boxes were to be interfaced to existing counters. Test systems were to be able to respond to the specified 50 MPH and 40 MPH speed thresholds and were to use moving averages over 3 - 6 minutes to smooth speed data. Alarms were to be transmitted as either FAX messages or as DTMF code. Complete traffic census data would also be available at incident detection sites by downloading during a specified time window on a daily basis. In its response to the initial proposals, the RCT stated that not enough detail had been given in the GTE proposal and asked how the ten sites would be grouped to permit consecutive alarm processing at two separate sites. Also, as in the case of the Traffic Census subtest, the RCT indicated that it would like to see some attempt at providing internal counters. In its revised proposal of November 22, GTE listed the proposed sites and repeated that counters would be external to the call box. GTE also stated that the speed thresholds would be programmed into the firmware of the inductive loop detectors, and that these would cause the call box to power up to transmit alarms. GTE now offered four transmission options in place of the two in the initial proposal: use of an E- mail format, use of commercial paging calls, DTMF code to the existing maintenance computer or the TMC, or FAX messages.

On December 21, face-to-face negotiations were carried out between GTE and the RCT. As a result of these negotiations, GTE was instructed to use counters that it would provide to interface to inductive loops that Caltrans had installed but not yet connected. In addition, GTE was instructed to decrease the number of sites to be used for this subtest to offset the addition of a limited visibility detection site for the Hazardous Weather Reporting subtest.

On January 23, 1995, a working group of the RCT met to recommend cuts in proposed test activities in order to bring them into line with the FOT budget. As a result of this meeting, GTE was instructed to modify its proposal to provide only six units. On February 6, GTE responded by proposing to provide six units, five using external counters and the other incorporating an internal counter. GTE proposed to use two of these units in all other subtests and three more in the CCTV Surveillance subtest.

A contract between the RTC and GTE was executed on June 26, 1995. At a TAC meeting on June 28, GTE distributed revised site configurations and a tentative installation schedule. Contrary to what had been proposed on February 6, most sites were now to be used for only one subtest. As before, six incident detection sites were proposed. One of these was also to be used in the Traffic Census subtest and another in the CMS subtest. Once again, specific sites were proposed. A meeting between Caltrans and GTE to review the sites was held on July 5; GTE received Caltrans' input at this meeting and issued the final list of sites in early September. In February 1996, these were reconsidered, and four of the six sites were changed.

GTE's incident detection systems were installed in early March 1996, and the basic design was finalized at some point prior to this. In its final form, alarms were determined by software in the counter and transmitted to the data collection point as FAX messages. Also, at some point, the design of GTE's incident detection systems was changed to use all internal counters -- that is, the counter cards were installed in the same call box cabinet as the cellular phone, rather than in a separate cabinet with an A/C power connection. One of the units that had previously been used in the Traffic Census subtest had employed an external counter, but this was replaced by an internal counter when the incident detection subtest was initiated at this site.

U. S. Commlink Systems

U. S. Commlink's initial proposal included test sites in both San Diego County and the San Francisco Bay Area. For each location, a single freeway corridor was to be instrumented, with multiple use of sites among the subtests. Incident detection test systems were proposed for two sites in each corridor. Of these two sites, one would use a Peek external counter, and the other would use a Schwartz Electro-Optics Autosense infrared detector. This proposal did not detail how threshold detection and alarm transmission would be accomplished. The RCT opposed the use of test sites in the San Francisco Bay Area as being outside the scope of the FOT, stated that at least one multiple site involving five or more call boxes was desired, and stated that the test objectives did not include comparison of sensor performance.

In its November 22 reply to the RCT's questions, U. S. Commlink defended the idea of a Northern California portion of the FOT; however, this was not agreed to by the RCT, and the idea was dropped after the December 21 negotiations. Also, U. S. Commlink defended the use of only two sites and the proposal to test alternative sensor technologies. Following the December 21 negotiations with the RCT, U. S. Commlink was asked to propose contiguous sites so that queue buildup could be observed. On January 10, 1995, U. S. Commlink responded to the RCT's summary of the December 21 negotiations by submitting a schematic diagram of its new proposed test configuration. This diagram indicated that four units would be provided and that A/C power would be required at all four sites.

Following the meeting of the RCT working group on January 23, 1995 and the subsequent meeting of the full RCT on February 1, U. S. Commlink was instructed to provide two units. On February 17, U. S. Commlink responded by proposing to provide the two units, one using a standard external counter and the other using an infrared sensor. U. S. Commlink proposed that each of these units be used in at least one other subtest.

A contract between the RCT and U. S. Commlink was executed on April 6, 1995. At a TAC meeting on May 10, U. S. Commlink distributed a set of "site descriptions" detailing site requirements and equipment to be installed at each site, but did not list specific sites. Following two meetings with personnel from Caltrans, specific sites were designated and presented to the RCT at its June 7 meeting. As it turned out, the incident detection sites were not contiguous. Subsequent to this, U. S. Commlink announced that it would be modifying the microprocessor card used in its call box units, and that it would be undertaking extensive bench testing of the proposed test systems. On October 20, a demonstration was held at U. S. Commlink headquarters, in which a number of test system capabilities were demonstrated. Transmission of incident alarms was not included in this demonstration, although transmission of traffic census data from the counters was. This demonstration was attended by representatives of the RCT, the Project Manager, and the Evaluator.

U. S. Commlink's overall strategy for the FOT was to produce a modified microprocessor card for its call boxes that could interface with up to four other devices such as weather sensors or traffic counters. In the case of the Incident Detection subtest, the original plan had been to use the same counters as had been used for the Traffic Census subtest. At Site 2, this meant that the manufacturer was expected to modify the Peek ADR-3000 that had been used for traffic census to provide incident detection capabilities. As it turned out, Peek was unable to do this within the time limits of the FOT. U. S. Commlink finally decided to replace the ADR-3000 counter with a Peek SOH device. This is an obsolete model that had been designed for use in tunnels and is no longer in production; however, it was capable of providing speed data that was used by the call box microprocessor card to evaluate multiple speed thresholds and transmit alarms, as required by the FOT. At Site 6, the Schwartz counter was modified to provide incident detection as well as traffic counts.

Subtest Schedule Adjustments

The incident detection subtest had originally been in Subphase 3 of the FOT. In August 1995 the RCT became concerned about schedule slippage, and its potential effect on FOT evaluation. In particular, it was felt that the Incident Detection subtest would require several months of data gathering, since the congestion alarms would depend on traffic conditions. Accordingly, a schedule revision was issued in which the Incident Subtest was moved to Subphase 2, with a target date of December 1 for completion of equipment installation.

During the next several months, the schedule continued to slip, due to the vendors' difficulties in getting equipment for Subphase 1 fully functional. This slippage delayed completion of test system designs for Subphase 2. By early January 1996, neither vendor was ready to begin installing equipment, and the RCT became concerned that the FOT might not be completed on schedule. At its January 4, 1996 meeting, the RCT decided to have San Diego SAFE send both vendors notices to cure default.

The notices were distributed at the January 11 TAC meeting, along with a schedule revision establishing "firm" dates by which data collection was to begin for each subtest. In the case of the Incident Detection subtest, the deadline was February 15. On January

26, U. S. Commlink informed the Project Manager that it would not be able to meet the deadlines for this subtest, and proposed the deadline be delayed until May 3.

The RCT was unwilling to allow this much delay, since all data gathering was supposed to be completed by mid-May. The Project Manager was authorized to negotiate with U. S. Commlink to determine whether its portion of the Incident Detection subtest should be terminated or rescheduled. As a result of these negotiations, the RCT agreed to a compromise in which U. S. Commlink would simplify its design and have the Incident Detection units operational by February 29.

Installation of Test System Equipment

Basic equipment used in this subtest was similar to that used in the Traffic Census subtest, except that counters had to have the additional capability of determining that alarm thresholds had been crossed. Both U. S. Commlink sites and two of the six sites used by GTE had also been used for the Traffic Census subtest, and in these cases, only minor equipment modifications were necessary. Equipment at the GTE traffic census sites had been installed in September 1995, although the loops at GTE Site 3/14 were not connected until February 1, 1996. At GTE Site 13 (known as Site 2 for the Traffic Census subtest) the external counter used for the Traffic Census subtest was replaced with an internal counter (the external counter unit did not have the capability to determine alarms) in early March 1996. Equipment at the four remaining GTE sites (7, 21, 22, and 23) was also installed in early March. Equipment at U. S. Commlink Site 2 had been installed on November 17, 1995, and that at Site 6 on December 6. Site 2 was converted from the Peek ADR-3000 counter that had been installed for the Traffic Census subtest to the Peek SOH used for incident detection in early May 1996; the incident detection features of the Schwartz device were activated as early as May 2, but the site was down for installation of a software upgrade until nearly the end of the month.

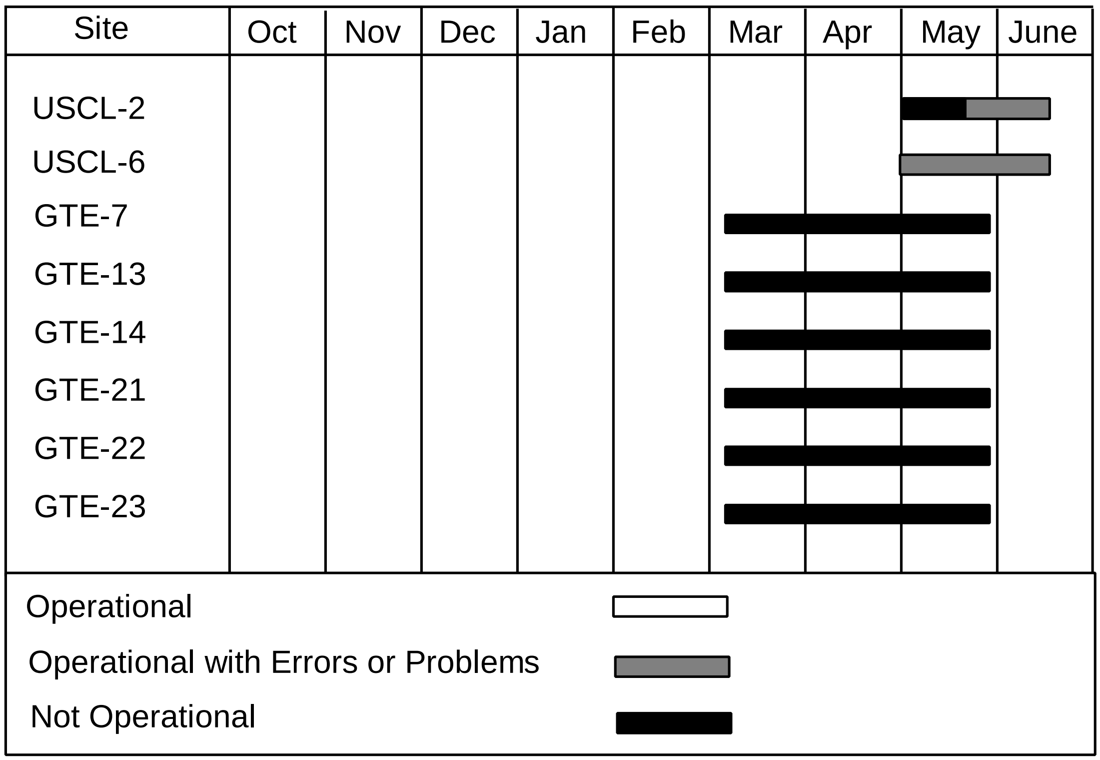
Conduct of Subtest

Shortly after the installation/conversion of GTE's incident detection sites, GTE reported that the counters were detecting speed thresholds, but that the alarms were not being transmitted successfully by the call boxes. This problem was apparently never resolved, since only one alarm was ever received at the data collection center.

U. S. Commlink's sites were converted to incident detection in early May, shortly before data collection for the FOT was scheduled to end. Because of this, data collection was extended from May 15 to June 13. At Site 2, numerous alarms were received throughout the period May 2 - June 13. At Site 6, the counter was down for installation of a software upgrade until the later part of May. Once this upgrade was completed, numerous alarms were received. In both cases, however, the validity of the alarms was questionable.

Figure 5 shows the periods during which the various incident detection test sites were operational.

Figure 5. Operational Status of Incident Detection Test Sites.



Data collected for this subtest consisted of FAX messages transmitting alarms. These messages recorded the date, time, location, and current speed category. This information was transferred by hand to a spread sheet for analysis. Data were analyzed by plotting times and durations of congestion incidents as indicated by the alarms and comparing these with Caltrans incident logs and with speeds derived from data from the San Diego ramp metering system, where this was available. Based on these analyses, it was concluded that the GTE systems and the U. S. Commlink infrared detector system were definitely not functioning properly and that the U. S. Commlink external-counter system was failing to transmit alarms during some periods of traffic congestion. Eventually, the CCTV installation located at U. S. Commlink Site 2 was used to verify that the external-counter system was sometimes failing to transmit alarms.

ANALYSIS OF TEST SYSTEM EFFECTIVENESS

System Adequacy

The adequacy of the various test system designs was determined by comparing the final designs with performance standards established by the RCT and published in the FOT Evaluation Plan. In addition, test systems were reviewed for conformity to any other specifications established by the Project Manager in the Request for Participation (RFP) or promised by the vendors in their responses. Finally, times and durations of congestion incidents were compared with Caltrans incident logs and with speed data, where this was available. Appendix E presents detailed comparisons of actual designs with performance standards and specifications related to the basic functionality of the test systems.

The GTE system design met most performance standards and specifications, at least in theory. Exceptions were that: 1) The data transmitted did not include the correct alarm message. The call boxes had previously been programmed to transmit the message "low visibility" as a part of the Hazardous Weather subtest. This message was never updated, so what was actually transmitted in the Incident Detection subtest was a low visibility warning rather than a congestion warning. 2) The performance standards implied that the system would transmit a character string suitable for recording in a computer file. The RCT later approved transmission of FAX messages as an alternative. Nevertheless, the use of FAX transmissions limits the system's potential usefulness, since the alarms cannot be integrated into the TMC's existing congestion display system. 3) The performance standards required that incident detection systems be capable of being remotely programmed to allow adjustments to speed thresholds. The GTE system was not capable of this. More importantly, however, the system as a whole did not function correctly. Only one alarm was ever transmitted to the data collection center. Review of Caltrans incident logs indicate that there were a number of incidents in the vicinity of these units; also, in one case, analysis of speed data derived from the San Diego ramp metering system indicated that there was recurring congestion at one of the sites. Based on this data, a number of alarms should have been received from all sites, and alarms should have been received on a daily basis from at least one site.

The U. S. Commlink external counter loop-detector system design met all standards except that 1) It could not be remotely programmed 2) It transmitted FAX messages rather than character strings and 3) The system did not actually send alarms every time a speed threshold was crossed; instead, the unit was programmed to repeat alarms at 20-minute intervals. Possibly as a result of this last feature, there were repeated alarms to the same speed level without any intervening alarm indicating that speeds had increased or decreased. This alarm-suppression feature was intended to prevent frequent repetition of alarms in the event of rapid speed oscillations about the threshold, but it was not exactly what the performance standards specified.

More importantly, when times and durations of incidents were analyzed, the alarms indicated considerably less congestion than is believed to occur in this section. The number, duration and severity of congestion incidents as indicated by the alarms were all less than expected. On the other hand, the pattern of alarms did roughly resemble that expected, with the greatest incidence of alarms occurring in the evening peak period. Also, alarms were received around the times of several incidents recorded in the Caltrans incident log. Eventually, by use of the video camera installed at this site as a part of the CCTV Surveillance subtest, it was possible to confirm that alarms were not always being sent when the section was congested. On the whole, it appears that although this device was not working correctly, the problems may have been subject to correction by minor adjustments.

The U. S. Commlink infrared detector system design met all standards except that it transmitted FAX messages rather than character strings and (as in the case of the external detector system) the alarms were not transmitted every time a threshold was crossed. This system was capable of being programmed remotely, although it was never possible to do this from the data collection center because Schwartz never supplied the necessary software. When incident alarms were analyzed, however, it did not appear that the unit was working correctly. For one thing, all alarms indicated the same speed level; apparently the full algorithm, which was to report three speed ranges, was never implemented. Moreover, the times of alarms were not as expected. This may be related to more general time-keeping problems that characterized this equipment (see Traffic Census Subtest Report). Finally, on one occasion the alarm system indicated an incident with a duration of more than eight hours. There is no record of any such incident having occurred. Based on these considerations, it does not appear that this device functioned correctly.

System Reliability

System reliability for this subtest was defined in terms of system availability, with a minimum system availability of 90 per cent being required by the performance standards. The GTE system never functioned correctly. The U. S. Commlink external counter loop-detector system was continuously available for the short period (approximately six weeks) that it was in operation. The U. S. Commlink infrared detector system was continuously available for the even shorter period of time it was in operation (around three weeks). In this case, however, the counter had a history of erratic operation during the Traffic Census subtest. Although the U. S. Commlink systems functioned reliably after adjustments (except for the accuracy of the alarm algorithms), the test was too short to draw conclusions about their long-term reliability.

COMPARISON OF TEST AND BASELINE SYSTEMS

System Adequacy

The baseline system appears to perform adequately, but none of the test systems appears to have performed adequately. In order to as useful as the baseline system in the San Diego TMC environment, the U. S. Commlink systems require further development to correct the apparent deficiencies in the algorithms and to provide alarm transmissions that can be integrated into the TMC's existing congestion display system. Such modifications are also required to make smart call box congestion alarm systems viable elsewhere. The critical feature of an improved alarm system is to provide the alarms in a form that can be evaluated by a computer program running continuously at the TMC. Once alarms are in this form, a variety of alarm and display options are available.

System Reliability

Caltrans personnel report that the reliability of the baseline system is adequate, although no exact figures were provided. Of the test systems, that provided by GTE did not function at all, and those provided by U. S. Commlink were inaccurate and were operational for too short a time to establish any meaningful measure of reliability.

ANALYSIS OF TEST AND BASELINE SYSTEM COSTS

Capital Costs

Capital costs were determined by having representatives of Caltrans District 11 structure bids for the installation of test and baseline systems at the sites actually used, and then asking the vendors what they would bid for these items as a part of a full-scale deployment of the system in question. For items not supplied by the vendors, standard Caltrans cost estimates were used. Capital cost estimates for sites involved in the Incident Detection Subtest are detailed in Appendix F. Note that for installations intended to serve more than one function, these cost estimates include some items that were not related to this subtest.

Capital cost comparisons are summarized in Table 5.

Table 5. Capital Cost Comparisons for Incident Detection Sites.

	Costs		Difference,
Site	Test System	Baseline System	Baseline-Test
USCL-2	$59,400	$69,100	$9,700
USCL-6	$75,920	$156,620	$80,700
GTE-7	$10,400	$51,150	$40,750
GTE-13	$10,710	$22,790	$12,080
GTE-14	$7,230	$14,595	$7,365
GTE-21	$10,410	$77,510	$67,100
GTE-22	$10,410	$24,140	$13,730
GTE-23	$10,410	$56,830	$46,420

From Table 5, it may be seen that although capital costs are highly site-specific, the test system involves a large advantage in capital cost at most of the test sites. This is primarily due to the high cost of trenching and installing telephone cables at most of these sites. In general, hardwire telephone infrastructure was not available in the immediate vicinity of these sites, even where A/C power was available. Under current Caltrans policy, moreover, any extensions of telephone lines must be routed through public right-of-way, which substantially increases the access distance in some cases.

Note also, in comparing costs at the U. S. Commlink sites, that the Schwartz infrared traffic sensor costs $6,500 for an installation that can cover a single lane. Loop detector installations cost from $1,100 to $3,300 for the counter plus $850 per loop, including the cost of installation and lane closures required for installation. This means that loop detector installations have a significant cost advantage where several lanes are involved. This is less important for incident detection than for traffic census uses, since it is not always necessary to collect data from all lanes; however, it does constitute a decided advantage for loop detectors.

Table 5 lists the total capital costs for the sites in question. Some of the equipment at the U. S. Commlink sites was not necessary for this subtest. Also, costs at most of the U. S. Commlink sites were heavily influenced by the cost of providing A/C power, and costs at all loop-detector sites were influenced by detector installation costs. Both external power costs and loop installation costs vary widely depending on the characteristics of the site. To give an idea of what smart call box incident detection systems might cost by themselves, and the impact of external power supply and loop installation costs, Table 6 lists site costs including only incident detection equipment, cost of external power supplies, and incident detection system costs exclusive of power costs and loop installation costs.

Table 6. Site Costs for Incident Detection Alone.

Site	Cost, Incident Detection Only	External Power and Loop Costs	Cost Exclusive of External Power and Loops
USCL-2	$50,200	$40,400	$9,800
USCL-6	$75,920	$58,220	$17,700
GTE-7	$10,400	$6,800	$3,600
GTE-13	$10,710	$7,100	$3,610
GTE-14	$7,230	$3,400	$3,830
GTE-21	$10,410	$6,800	$3,610
GTE-22	$10,410	$6,800	$3,610
GTE-23	$10,410	$6,800	$3,610

Operating Costs

Operating costs include telephone charges and maintenance costs. Current telephone charges paid by Caltrans for conventional telephone service and San Diego SAFE for cellular service are $14.00 per month per line for conventional service and $10.00 per month per line for cellular service. This means that the test systems actually have a slight advantage in terms of telephone charges in the San Diego area, although this may not be true elsewhere.

Although determination of maintenance costs for smart call box systems was a major goal of the FOT evaluation as initially conceived, the data collected are not adequate for this purpose. This is due to the fact that the systems involved in this subtest were operational for only a short period of time. Also, it should be recognized that maintenance costs of deployed systems may depend heavily on certain institutional decisions, particularly that of whether maintenance is to be done by the vendors under contract or in-house by public agencies.

Life-Cycle Costs

Given that capital costs vary widely depending on site conditions (particularly access distances to hardwire telephone systems) and that maintenance costs for the test systems are uncertain, it is not possible to determine exact life cycle costs for the test systems or to compare them with those of the baseline system. A more reasonable approach is to determine the break-even points between the test and baseline systems, based on telephone access distances, differences in maintenance costs, and differences in assumptions about interest rates. The tables below give the maximum additional maintenance cost per unit for the smart call box system at break-even, as a function of the access distance for conventional telephone and the assumed interest rate.

Table 7 gives break-even maintenance costs for systems with internal counters (such as the GTE systems) and Table 8 those for systems with external counters (such as U. S. Commlink Site 2). The difference between these two designs is the cost of the additional cabinet housing the external counter. All calculations are based on an assumed life of 10 years with no salvage value, and the monthly telephone charges listed in the section on “Operating Costs.” In addition, all calculations assume that for the baseline system both trenching and cabling is required for the full access distance listed, but that there are no additional costs in providing hardwire connections, such as jacking conduits under traffic lanes. Trenching casts are assumed to be $10.00 per foot, and cabling costs to be an additional $1.00 per foot, for a total of $11.00 per foot. These cost assumptions are based on estimates by Caltrans.

Table 7. Break-Even Maintenance Cost Differences for Smart Call Boxes with Internal Counters.

Access Distance for Baseline System, Ft.	Max. Difference in Annual Maintenance Costs (Call Box - Baseline) for Given Interest Rate		
	5%	7.5%	10%
100	$333	$369	$406
200	$475	$529	$585
500	$903	$1,010	$1,122
1,000	$1,615	$1,811	$2,018
2,000	$3,039	$3,414	$3,809
5,000	$7,313	$8,222	$9,181
10,000	$14,435	$16,235	$18,135

Table 8. Break-Even Maintenance Cost Differences for Smart Call Boxes with External Counters.

Access Distance for Baseline System, Ft.	Max. Difference in Annual Maintenance Costs (Call Box - Baseline) for Given Interest Rate		
	5%	7.5%	10%
100	- $120	- $141	- $164
200	$22	$19	$15
500	$449	$500	$553
1,000	$1,162	$1,301	$1,448
2,000	$2,586	$2,904	$3,239
5,000	$6,860	$7,712	$8,611
10,000	$13,982	$15,725	$17,565

For the sites involved in this subtest, telephone access distances varied from 115 ft to 7,100 ft, with the median distance being around 1,850 ft. Thus for sites typical of this subtest, smart call box systems are likely to have a cost advantage over conventional systems so long as the difference in maintenance costs does not exceed $2,500 per unit for installations with external counters or $3,000 for those with internal counters.

CONCLUSIONS

This section of this report documents the evaluation of the Incident Detection Subtest of the Smart Call Box FOT. Objectives of the evaluation were to determine the cost-effectiveness of using smart call boxes for the processing and transmission of incident alarms. This included assessing the effectiveness of the various test systems, estimating life cycle costs, and identifying tradeoffs among the baseline system and the various test systems. In addition, the subtest evaluation addressed issues such as potential improvements to the designs tested in this FOT and actions related to specific test systems that should be undertaken prior to deployment. A more general discussion of actions required before deployment may be found in the subtest report on Institutional Issues. Major conclusions include:

1. None of the systems tested functioned adequately. The U. S. Commlink systems transmitted numerous alarms, but these did not appear to be accurate. The GTE system did not function at all. In addition, lack of adequate interface with TMC data analysis and display systems is a major limitation for all systems tested.

2. System availability was adequate for both U. S. Commlink systems for the short period of time they were in operation. The FOT did not provide enough experience with these systems to allow conclusions about their long-term reliability, however. It should also be noted that the infrared detector system had a rather poor record for reliability in the Traffic Census subtest, and problems with the accuracy of speeds and volume counts reported by this unit do not appear to have been completely resolved (see Traffic Census subtest report).

3. Capital costs of the systems tested here are expected to vary widely depending on the type of system, the cost of supplying external A/C power where that is required, and the cost of providing detectors. Overall costs of the GTE system were on the order of $10,000, or $3,600 exclusive of loop installation costs. The overall cost of the U. S. Commlink external-counter system was about $50,000, much of which was due to the cost of supplying A/C power to the test site; the cost of this system was around $10,000 exclusive of external power supply and loop installation costs. The U. S. Commlink infrared detector system cost about $76,000, or about $17,700 exclusive of power supply costs. Costs for U. S. Commlink systems consider only those components installed at each site that were used for processing and transmission of incident detection alarms.

4. For most sites, use of infrared detectors is significantly more expensive that use of loop detectors. This is due both to the high cost per unit for the detector-counter unit and to the fact that these detectors cover only one lane apiece. For incident-detection use, it may be possible to monitor only one lane at a given site, in which case this limitation is much less important.

5. The cost-effectiveness of the various test systems, when compared with the baseline system, depends on access distances to the hardwire telephone system and maintenance costs for the smart call box systems. Since maintenance costs for the test systems could not be determined, these break-even points between the test systems and the baseline system may be stated in terms of differences in maintenance cost. For telephone access distances typical of the FOT, break-even annual maintenance cost differences are on the order of $2,500 to $3,000 per unit.

6. If it is necessary to monitor multiple lanes, loop-detector based systems will generally be more cost-effective than infrared-detector-based systems (assuming similar reliability and maintenance costs).

7. Continued testing of the systems involved in this subtest should be undertaken prior to deployment. Goals of such testing should be to correct problems with the alarm routines and verify their accuracy and to establish the reliability and maintenance costs of the systems. Further development and testing of congestion-detection algorithms (particularly their data-smoothing features) is also desirable. Also, development of an effective interface with TMC data systems is necessary prior to deployment.

8. Design enhancements that would improve the utility of the test systems include 1) successful combination of traffic census and low speed alarm capabilities in a single counter and 2) development of a successful system that does not require external power. Both vendors attempted unsuccessfully to provide both traffic census and alarm capability with a single device. In the case of the GTE system, the counter was said to have possessed this capability, but system integration failures apparently prevented alarms from being relayed to the data collection center. GTE also attempted to provide incident detection capability with a device that did not require external power, but was unsuccessful.

The subtest also provided several important lessons related to technology, system design concepts, the design process, and the process of testing and evaluating the systems. These included:

1. Infrared sensor technology is expensive, and these devices appear to still be in the experimental stage. The model tested here may need further development in order to be reliable.

2. System integration was a major design issue for the systems involved in this subtest. Some consequences were 1) More time should have been allowed for design. Just because all the components are "off-the-shelf" does not mean that they will work well together. Identifying and correcting the resulting software problems is very time consuming. 2) It is unrealistic to expect that the components will truly be "off-the-shelf," even if a satisfactory product already exists. Traffic counter manufacturers, in particular, introduce improved products from time to time and naturally want to use the latest version when new systems are developed. "Upgrades" tended to result in

software incompatibilities with equipment that had been compatible with the previous version. 3) A standard communications protocol for traffic counters and similar devices that recognizes the requirements of wireless communications systems is highly desirable. This standard should address communications and software design for all interacting components to include the counters, call boxes, maintenance computer, and TMC data collection software. Given the tendency for counter equipment to evolve, such a standard may be the only way to ensure that smart call box systems will not need to be reinvented every time a new model of counter is introduced. It is questionable, however, whether the market for smart call box systems is large enough to support development of such a protocol. Any such protocol would form part of the National Transportation Communications for ITS Protocol (NTCIP) standards currently under development (*2*). In order to provide standards specifically adapted to smart call boxes, the current NTCIP effort will need to be extended to include standards for smart call box higher level interactions.

3. Most of the data processing for the systems involved in this subtest took place in the counters, with the call boxes serving primarily as a data communications link. The U. S. Commlink external counter system was an exception to this, in that the call box microprocessor did evaluate data from the Peek SOH device, rather than just acting on an alarm pulse. The call box microprocessor card is essential to all the systems designed for this subtest, however, since it generated the alarm message.

4. In their current state of development, smart call boxes are probably not capable of handling complicated incident detection algorithms that involve combining data from multiple locations. It is not clear that the accuracy of algorithms of this sort is great enough to warrant further development to adapt smart call box systems to them. A possible alternative, which would get around some of the limitations of the speed alarm approach used in the FOT would be to develop an expert system in which TMC software interprets speed alarms in terms of time of day, location, and possibly data downloaded from nearby locations.

5. The evaluation objectives of this subtest were based on the false assumption that system functionality would not be a major problem. In retrospect, the subtest evaluation should have focused on system functionality. Evaluation of reliability and maintenance requirements requires a much longer test, and should not have been undertaken until after basic functionality was well-established.

6. In selecting sites for this subtest, more attention should have been paid to the need for verifying traffic conditions. In several cases, no alternative source of automatically-collected traffic data was available in the immediate vicinity. This greatly limited ability to verify the accuracy of the congestion detection algorithms.

HAZARDOUS WEATHER CONDITIONS DETECTION AND REPORTING SUBTEST

SUBTEST OBJECTIVES

The objective of this subtest was to evaluate the cost-effectiveness of smart call boxes for processing and transmitting hazardous weather alarms. This included determining the following:

- The relative effectiveness of several different test systems involving smart call boxes for processing and transmitting hazardous weather alarms when compared with one another and with a baseline system consisting of a series of weather sensors connected by hard-wire telephone line to computers at Caltrans maintenance stations. Effectiveness was defined to include the functional adequacy, accuracy, and reliability of the data processing and data transmission provided.

- The projected life-cycle costs of different test systems involving smart call boxes used to process and transmit hazardous weather alarms, as compared to one another and to the baseline system.

- Tradeoffs (if any) between use of the various smart call box systems and hard-wire telephone systems for the processing and transmission of hazardous weather alarms.

SUBTEST DESCRIPTION

Four smart call box units were tested. These included a total of three different test system configurations developed by two separate vendor teams. The vendor team headed by GTE designed and installed two units involving use of sensors to detect fog or other low visibility conditions. The other vendor team, headed by U. S. Commlink, designed and installed two units. The first of these had originally been planned to be connected to a Vaisala Weather System but was later changed so as to involve a combination of a Davis Weather System and a Jaycor visibility sensor; however, only the visibility sensor was actually installed. The second used a Davis Weather System to detect high wind conditions. U. S. Commlink call boxes used in this subtest were also used in the Traffic Census Subtest and in one case, the CCTV Surveillance Subtest. Appendix B documents overall system configurations for the two vendor teams, showing the units used in each subtest.

In each case, the overall system involved field units consisting of weather or visibility sensors and call boxes that reported to a data collection center at the Project Manager's headquarters. All systems developed for this subtest integrated call boxes with off-the-shelf weather sensors. In all cases a major part of the information processing capability of the system resided in the sensor unit, rather than in the call box. Sensor software was used to interpret analog signals from the anemometer or visibility detector, convert these to digital signals, compare these with predetermined thresholds to set alarms, and store data in memory for downloading. Call boxes were used primarily as communications devices, transmitting alarms and (at least in the case of U. S. Commlink systems) downloading data in response to prompts from the data collection center.

The following is a detailed description of the sites and equipment included in each test system. Block diagrams showing the functioning of these systems are presented in Appendix C.

GTE Systems

- ***System Configuration: Visibility Sensor***

    Equipment:

    1- GTE Call Box
    1 - Solar Charging Assembly
    1 - Jaycor Visibility Sensor

    Sites:

    - I-5, Post Mile SB 35.200, Call Box Number 5-352, Del Mar Heights. GTE Site # 4.
    - SR-75, Post Mile NB 17.600, Call Box Number 75-176, Silver Strand. GTE Site # 5.

U. S. Commlink Systems

- ***System Configuration 1: Jaycor Visibility Sensor***

    Equipment:

    1 - U. S. Commlink, Smart Card System
    1 - Cubic Call Box Assembly
    1 - Call Box Mounting Assembly
    1 - Jaycor Visibility Sensor
    1- Solar Charging System

Site:

- I-5, Post Mile NB 36.826, Call Box Number 5-368, North of Via de la Valle. U. S. Commlink Site # 1.

- ***System Configuration 2: Davis Weather System***

Equipment:

1 - U. S. Commlink, Smart Card System
1 - Cubic Call Box Assembly
1 - Call Box Mounting Assembly
1 - Davis Weather System
1 - Solar Charging System

Site:

- I-8, Post Mile EB 39.300, Call Box Number 8-392, at Japatul Road (SR-79). U. S. Commlink Site # 5.

Figure 6 is a map showing the location of these sites.

Data Transmission and Processing Tasks

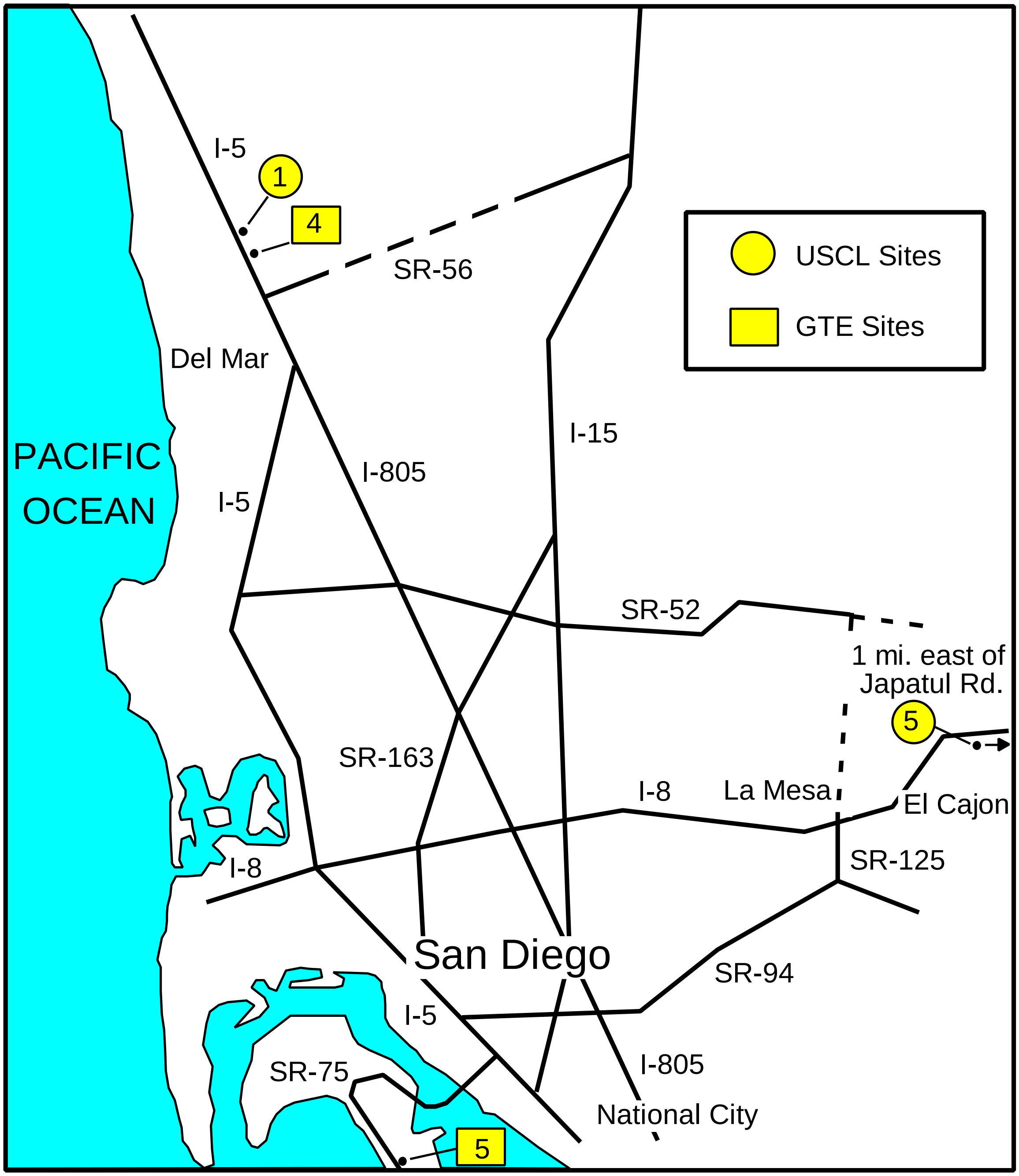
For this subtest, all test systems were required to be capable of determining and transmitting hazardous weather alarms based on predetermined threshold conditions. These requirements are detailed in the subtest system Performance Standards in Appendix D.

SUBTEST CHRONOLOGY

Development of Performance Standards and Specifications

As envisioned in the Evaluation Plan, development of performance standards, specifications, and test system designs were to have been distinct phases in the development of test systems. Performance standards were to have been determined by Caltrans District 11 (as the “customer”). The Project Manager was to refine these into specific functional specifications, which would in turn be used by the vendors to develop detailed specifications and designs.

Figure 6. Map Showing Test System Sites the Hazardous Weather Detection and Reporting Subtest.



In practice, however, there was a great deal of overlap between the development of standards, specifications, and system designs, with formal performance standards being adopted late in the process and continuing to evolve thereafter. In the case of the Hazardous Weather Detection and Reporting subtest, the original FOT proposal of October 1992 called for six sites. One set of sites was to be located at high elevation and was to be designed to measure and report the potential onset of road icing and wind shear. The other set of sites was to be located in areas subject to coastal fog, and was to be designed to measure and report the onset of reduced visibility conditions. The reduced visibility sites were to include both freeway and two-lane highway locations. Shortly after the FOT was funded, the Work Plan was revised in October 1993 to reduce the proposed number of sites to two.

On July 27, 1994 the initial draft of the project Request for Participation (RFP) was released at a meeting of prospective vendors. This draft RFP called for two units to be provided. Call boxes were to be able to detect and transmit alarms when predetermined threshold parameters were reported by weather sensors. Weather conditions of interest were stated to include temperature, dew point, fog, wind velocities, and icing. The RFP further required that systems must be capable of being remotely programmed to allow adjustments to weather threshold parameters. The RFP also stated that call boxes were to be linked to changeable message signs (CMSs) used in Subtest 4. Prospective vendors expressed concerns about these criteria. In particular, it was pointed out that threshold levels tend to be built into weather sensors, so that remotely-programmed adjustments to thresholds would be difficult if not impossible. Nevertheless, there was no modification of this section in the final RFP of August 15.

A meeting between the Evaluator and various members of Caltrans District 11 operations staff was held on August 25 to discuss performance standards. At this meeting, it became clear that the test systems being proposed for the FOT were substantially different from the baseline system, in which weather sensor output was being transmitted continuously to computers at various locations. At the meeting, it was proposed that the status of five weather condition indicators be transmitted every 15 minutes, but that no alarms be involved. The five weather condition indicators were to be air temperature, pavement temperature, humidity, wind speed and direction, and precipitation. When draft Performance Standards were discussed by the RCT on October 5, however, it was decided that the purpose of the FOT was not to duplicate the existing weather detection system, but rather to develop a new system for the TMC. Consequently, the FOT would involve determination and transmission of alarms. In addition, the final version of the Performance Standards omitted mention of any specific weather conditions to be monitored, and stated that the required alarm conditions were yet to be determined.

Development of Test System Designs

Development of designs for the test systems was carried out by the vendors, with the scope of the test, as well as certain design details, subject to negotiation with the RCT. This process began with the vendors’ preparation of proposals, which were submitted in late October 1994, and continued into the field test portion of the project. In all cases, the test systems were designed by putting together preexisting components, so that the major design challenge was achieving end-to-end system integration. For the most part, this involved resolving software incompatibilities. Some of these did not surface until after the initial installation of equipment in the field, so that some of the system design actually took place during a fairly extended shakedown period. The was particularly true of the GTE system, which was in operation over an extended period of time.

GTE Systems

GTE's initial proposal was to provide six units for the Hazardous Weather Detection subtest. Two units were to provide low-visibility alarms. These would provide alarms whenever visibility was less than 300 feet, and would provide for programmable visibility threshold levels and alarm reset intervals. Alarms would be communicated by means of PC-type FAX messages or DTMF code. Two units were to detect excessive wind velocity. These would read wind speed and direction from anemometers and wind direction vanes and send alarms when predetermined thresholds were exceeded. Alarms for these units would also be communicated by means of PC-type FAX messages or DTMF code. Two additional units were to be used for roadway ice detection. GTE stated that in this case the method of detection was to be determined, since no cost-effective method had yet been identified.

In its response to the initial proposals, the RCT stated that six sites exceeded the test requirements and that the specific forms of notification to the CHP or Caltrans TMC were subject to RCT approval. The RCT also pointed out that of the three types of systems proposed, the sensors were identified for only one. The RCT asked that the specific device to be used to detect wind speed and direction be identified and remarked that in the case of road icing, the sensing device appeared to be nonexistent. In its revised proposal of November 22, GTE reduced the number of proposed sites to two, one to be used for low visibility detection and the other for high wind speed detection. GTE also listed specific proposed sites, gave details as to the type of wind velocity and direction sensors proposed, and offered four transmission options in place of the two in the initial proposal. These were an E- mail format, commercial paging calls, DTMF code to the existing maintenance computer or the TMC, and PC-type FAX.

On December 21, face-to-face negotiations were carried out between GTE and the RCT. As a result of these negotiations, GTE was instructed to use the E-mail format alarm option and to add a second low-visibility detection site.

On January 23, 1995, a working group of the RCT met to recommend cuts in proposed test activities in order to bring them into line with the FOT budget. As a result of this meeting, GTE was instructed to modify its proposal to provide two low visibility detection units and to eliminate the wind speed detection unit. On February 6, GTE responded by proposing to provide two low-visibility detection units, both of which were to be used in all other subtests.

A contract between the RTC and GTE was executed on June 26, 1995. At a TAC meeting on June 28, GTE distributed revised site configurations and a tentative installation schedule. Contrary to what had been proposed on February 6, most sites were now to be used for only one subtest. As before, two low-visibility detection sites were proposed and specific sites were listed. A meeting between Caltrans and GTE to review the sites was held on July 5; GTE received Caltrans' input at this meeting and issued the final list of sites in early September.

GTE's basic design for its low-visibility detection systems was finalized some time prior to their installation in early September. In its final form, alarms were determined by software in the sensor and transmitted to the data collection point as FAX messages (not E-mail, as had been discussed in December). Also, there was no provision for notifying the data collection center once visibility exceeded the threshold after an alarm, although sensors were programmed to reset themselves after five minutes. This came as something of a surprise to the RCT, which had assumed that the alarm systems employed in the FOT would involve some sort of "all clear" signal; however, the performance standards had made no mention of any such requirement. In addition, there were several system integration problems that were resolved during the shakedown phase described in a subsequent section of this report.

U. S. Commlink Systems

U. S. Commlink's initial proposal included test sites in both San Diego County and the San Francisco Bay Area. For each location, a single freeway corridor would be instrumented, with multiple use of sites among the subtests. Hazardous weather detection systems were proposed for two sites in each corridor. One of these sites would use a complete Vaisala weather station to provide data on wind speed, temperature, barometric pressure, and surface temperature, and the other would involve a low-visibility detection system. The proposal stated that the call boxes would not only be able to generate and transmit alarms, but also that actual weather data would also be transmitted to the host computer at the TMC. In its response, the RCT opposed the use of test sites in the San Francisco Bay Area as being outside the scope of the FOT, asked what type of computer and software would be required at the TMC to process weather data, and asked whether the link between the Vaisala weather station and the call box would be wire or cellular.

In its November 22 reply to the RCT's questions U. S. Commlink defended the idea of a Northern California portion of the FOT; however, this was not agreed to by the RCT, and the idea was dropped after the December 21 negotiations. U. S. Commlink also stated that the required computer was an IBM-compatible 486PC running Windows, with other software to be supplied by weather system vendors, and that the call box would be connected to the Vaisala weather station by wire. Following the December 21 negotiations with the RCT, U. S. Commlink was asked to submit costs for the two systems previously proposed. On January 10, 1995, U. S. Commlink responded to the RCT's summary of the December 21 negotiations by submitting a schematic diagram of its new proposed test configuration. This diagram indicated that four units would be provided: two complete weather stations (presumably other than Vaisala), one low-visibility sensor, and one call box interfaced to a Vaisala weather station. Of these, the low-visibility sensor and one of the complete weather stations would require A/C power.

Following the meeting of the RCT working group on January 23, 1995, U. S. Commlink was instructed to provide one complete weather station and to delete the low-visibility sensor, the interface to the Vaisala equipment, and one of the complete weather stations. On February 17, U. S. Commlink responded by proposing to provide two complete weather stations. U. S. Commlink proposed that each of these units be used in at least one other subtest.

A contract between the RCT and U. S. Commlink was executed on April 6, 1995. At a TAC meeting on May 10, U. S. Commlink distributed a set of “site descriptions” detailing site requirements and equipment to be installed at each site, but did not list specific sites. Following two meetings with personnel from Caltrans, specific sites were designated and presented to the RCT at its June 7 meeting. Subsequent to this, U. S. Commlink announced that it would be modifying the microprocessor card used in its call box units, and that it would be undertaking extensive bench testing of the proposed test systems. On October 20, a demonstration was held at U. S. Commlink headquarters, in which a number of test system capabilities were demonstrated. These capabilities included transmission of alarms from a Davis weather station. This demonstration was attended by representatives of the RCT, the Project Manager, and the Evaluator.

Installation of Test System Equipment

The installation phase of the subtest included installation of field equipment and installation of communications and computer equipment at the offices of the Project Manager to collect data. In principle, it also included integration of these two systems to the point that automatically-collected data could be transmitted successfully to the Project Manager’s offices; however, there were lingering problems of system integration which extended into the test itself.

Equipment configurations for the hazardous Weather Reporting subtest are given in the Subtest Description section above. Test system installation sites are shown in Figure 6.

Communications and computer equipment installed at the Project Manager’s offices consisted of two suites of equipment, one intended to interface with GTE’s field equipment the other to interface with U. S. Commlink’s equipment. Purchase and installation of this equipment was timed to coincide with the vendors’ installation of field equipment. The first equipment suite, dedicated to the GTE portion of the test, was installed around the beginning of September 1995 and that dedicated to U. S. Commlink around the beginning of October.

Equipment was installed at the two GTE sites on September 7 and September 8, 1995. The Davis Weather Station at U. S. Commlink Site 5 was installed on November 1, 1995, but was not immediately connected to the call box. On November 14, it was discovered that the anemometer had been accidentally broken off its pole, but no immediate action was taken to repair it. In December, U. S. Commlink announced that its multiport communications protocol, which was necessary to operate both the weather and traffic census systems at this site simultaneously, was operational; however, in early January 1996 the weather station itself was removed for trouble-shooting. Later in the month, the anemometer was repaired.

At the January 4, 1996 meeting of the RCT, concern was expressed that the FOT was seriously behind schedule. Particular concerns included the failure of the GTE traffic census units to provide successful transmissions to the data collection point, the failure of U. S. Commlink's infrared sensor unit to function properly, and lack of progress by U. S. Commlink in getting its weather stations operational. As a result of these concerns, the RCT refused to fully fund vouchers that GTE had submitted and instructed San Diego SAFE send both vendors notices to cure default.

The notices were distributed at the January 11 TAC meeting, along with a schedule revision establishing "firm" dates by which data collection was to begin for each subtest. In the case of the Subphase 1 subtests (Traffic Census and Hazardous Weather Reporting) the deadline was January 26. On January 26, U. S. Commlink informed the Project Manager that it would not be able to meet the deadlines for its weather stations, and proposed that they be delayed until April 12 for the Davis Weather Station and April 19 for the Vaisala installation.

The RCT was unwilling to allow this much delay, since high wind and low visibility conditions would be unlikely to occur as late as April. The Project Manager was authorized to negotiate with U. S. Commlink to determine whether its portion of the Hazardous Weather Subtest should be terminated or rescheduled. As a result of these negotiations, the RCT agreed to a compromise in which the Vaisala station was to be dropped from the test, an additional Davis weather station and a Jaycor visibility device were to be added at Site 1, and both systems were to be operational by February 15.

Neither of these deadlines was met. The Davis weather station at Site 5 was reinstalled in early March, but by this time the cellular phone at Site 5 had failed and had been removed for repairs. U. S. Commlink reported that an alarm had been sent manually, but that the unit did not appear to be sending alarms in response to actual weather conditions. The site was finally accessed from the data collection center on April 5. At Site 1, the Jaycor sensor was installed in early March but the Davis weather station was never installed and was eventually dropped from the test.

Conduct of Subtest

The GTE visibility systems experienced a number of minor malfunctions and system integration problems during September and October 1995. These included a firmware problem, which was corrected in September; problems in accessing the remote unit's stored data from the GTE maintenance computer, which were corrected in October; false solar panel alarms at Site 4 in October; and a corrupted maintenance call scheduling file in the GTE maintenance computer, corrected in late November. A more persistent problem was that the field units reinitialized themselves every time there was a power interruption, so that the date, time, identification string, and stored data were frequently lost. This problem did not prevent the units from sending alarms, but it did complicate data gathering. This problem was finally corrected by installing a separate lithium battery to provide a continuous power source for the sensors. Site 5 was modified to include this battery on December 1; modification of Site 4 took place on December 15.

Otherwise, the GTE systems performed as expected, with numerous fog alarms transmitted to the data collection point beginning in November 1995 and continuing with diminishing frequency through the winter. The last alarm was received from Site 5 on May 1, 1996. Although it was not possible to actually verify conditions at the sites at the time the alarms were received, they did occur at reasonable times and with reasonable frequency. Also, Jaycor performed independent verification of the accuracy of the sensors at its headquarters in La Jolla, California, which is fairly close to GTE Site 4.

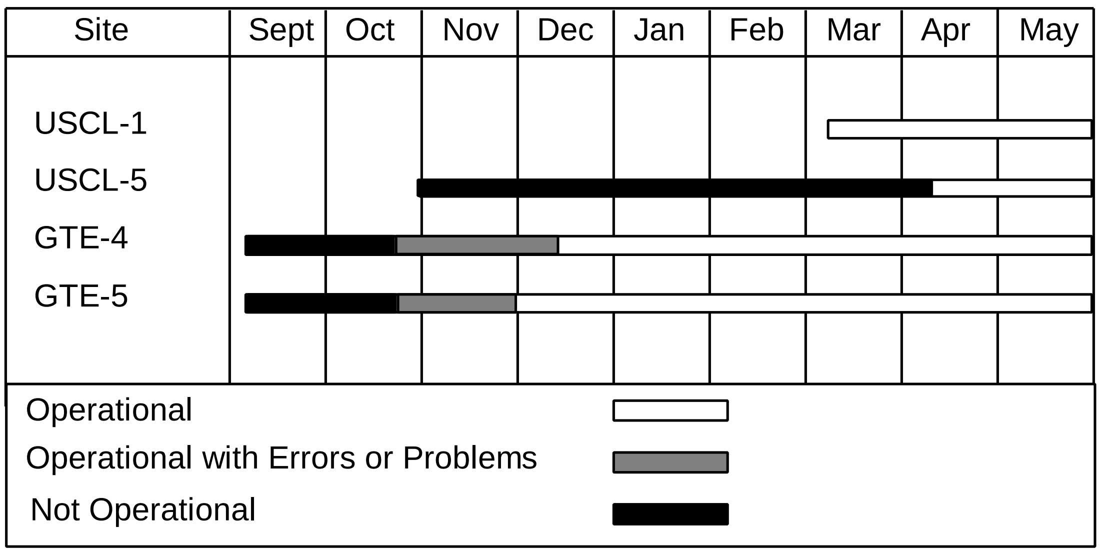
It should be noted that 1995-96 was an exceptionally foggy year in the San Diego area. This was particularly true of the month of November. On November 25, two major multiple-vehicle accidents involving fog occurred, one on Interstate 5 and the other on Interstate 805. These accidents were in the general vicinity (but not in the immediate vicinity) of GTE Site 4, and they contributed to interest in the results of this subtest. Because of the success of this subtest and the widespread interest in visibility detection, an early results report issued by the Project Manager on January 31, 1996 recommended that it be continued and expanded to include a network of visibility sensors on I-5 and I-805. By June 1996, no action had been taken on this recommendation, however.

At the April 11 TAC meeting, shortly after the reinstallation of the Davis weather station at U. S. Commlink Site 5, U. S. Commlink reported that the alarms were still not functioning correctly: calls were being received, but no messages were being downloaded. Meanwhile, U. S. Commlink had been successful in downloading weather data from this site, and had decided to lower the windspeed threshold from 30 mph to 20 mph to increase the probability of alarm conditions. Finally, on April 16 multiple alarms were successfully transmitted from Site 5 to the data collection point. These alarms continued on a regular basis during the rest of April and May.

No visibility alarms were ever received from U. S. Commlink Site 1, except for some that were induced artificially. This was presumably because the system did not become operational until after the end of the fog season, although a single alarm was received from GTE Site 4, about 1.6 miles south of this location, on March 19.

Figure 7 shows the periods during which the various hazardous weather detection test sites were operational.

Figure 7. Operational Status of Hazardous Weather Detection Test Sites.



ANALYSIS OF TEST SYSTEM EFFECTIVENESS

System Adequacy

The adequacy of the various test system designs was determined by comparing the final designs with performance standards established by the RCT and published in the FOT Evaluation Plan. In addition, test systems were reviewed for conformity to any other specifications established by the Project Manager in the Request for Participation (RFP) or promised by the vendors in their responses. Actual performance of the systems was evaluated by comparing times alarms were received with the general weather conditions known to have existed. Unfortunately, it was not possible to verify the exact conditions at the field sites. Appendix E presents detailed comparisons of actual designs with performance standards and specifications.

In general, the test systems involved in this subtest functioned adequately; however, the performance standards may not have been complete, and were not fully met by the test system designs. Major concerns about the functionality of the hazardous weather alarm systems in a TMC environment are:

1. The performance standards omitted to mention that an all-clear signal was needed; consequently the test systems do not provide one. Both do provide for periodic resetting of the sensors, or for repeated alarms when alarm conditions persist. This provides some capability for the TMC to determine the persistence of an alarm condition; however, an explicit all-clear signal would be better. Also, it might have been better to have had multiple alarm thresholds for visibility ranges and wind speeds, as was the case for traffic speeds in the Incident Detection subtest. Once again, this was overlooked in the development of the performance standards.

2. Neither system provides for remote resetting of alarm thresholds. This was called for by the performance standards, but the standard appears to have been incompatible with the capabilities of off-the-shelf sensor technology. This is not a critical defect, since resetting of thresholds is not expected to be a frequent event; however, the ability to reset thresholds remotely would be a convenience.

3. The use of FAX messages to send alarms is probably adequate but limits automation of the alarm process at the TMC end. It would probably be better for alarms to be received by some sort of software running continuously in the background on TMC computers, so that alarms could be processed and displayed in a variety of formats. As it is, the only “alarm” is one that indicates that a FAX message has been received.

4. In the case of the visibility alarms, isolated sensors may not be very useful. Rather, what may be required is a carefully designed network of alarm stations which can provide advance warning of the approach of fog.

System Reliability

The systems involved in this subtest appear to have been highly reliable, once initial problems were corrected. In the case of the U. S. Commlink systems, however, the period of time during which the units were fully operational was too short to gain much insight into their reliability. Also, since the systems in question were only in contact with the data collection center when they were either sending alarms or when the data collection center contacted them, it is hard to know whether they were continuously functional or not.

COMPARISON OF TEST AND BASELINE SYSTEMS

System Adequacy

Both test and baseline systems appear to be adequate for the tasks involved in this test. Major questions about adequacy center around integration of the systems into the TMC’s operations. At present, the baseline systems, at least as installed in the San Diego area, provide continuous data. Response to this data requires that a human operator recognize that a hazardous condition exists, and this may not occur due to inattention. On the other hand, the test systems provide alarms, but these consist of only FAX messages. In order to be really useful in the TMC environment, both systems require further development to provide effective alarms at the TMC end. The continuous data from the baseline system could be screened automatically at the TMC to set alarms; meanwhile, a more effective system for posting alarms would be a major improvement in the test system.

Once an alarm is received, the baseline system allows for better monitoring of ongoing conditions. As indicated in the section on “System Adequacy” the systems tested here do provide for periodic updating of alarms, but further improvements, such as multiple alarm levels and automatic all clear signals, will be required to make them as effective as the baseline system.

Also, in the case of both systems, there may be an issue of what to do about alarms that are received at times of day when the TMC is not staffed. This is of particular concern in the case of fog alarms, since these were often received late at night.

System Reliability

The reliability of both the test and baseline systems appears to be adequate. The FOT provided too little experience with the U. S. Commlink systems to allow positive statements about their reliability relative to the baseline system, however.

ANALYSIS OF TEST AND BASELINE SYSTEM COSTS

Capital Costs

Test system costs include capital costs, maintenance costs, and the cost of cellular airtime. Capital costs were determined by having representatives of Caltrans District 11 structure bids for the installation of the test systems at the sites actually used, and then asking the vendors what they would bid for these items as a part of a full-scale deployment. Estimated capital costs for sites involved in the Hazardous Weather Reporting Subtest are detailed in Appendix F. Note that for installations intended to serve more than one function, cost estimates include some items that were not related to the Hazardous Weather Reporting Subtest.

Capital cost comparisons are summarized in Table 9.

Table 9. Capital Cost Comparisons for Hazardous Weather Reporting Sites.

Site	Costs		Difference,
	Test System	Baseline System	Baseline-Test
USCL-1	$44,130	$77,480	$33,350
USCL-5	$7,815	$110,915	$103,100
GTE-4	$4,900	$84,900	$80,000
GTE-5	$4,900	$32,400	$27,500

From Table 9, it may be seen that although capital costs are highly site-specific, the test systems involve a large advantage in capital cost at all sites. This is primarily due to the high cost of trenching and installing telephone cables at most of these sites. In general, hardwire telephone infrastructure was not available in the immediate vicinity of these sites. Under current Caltrans policy, moreover, any extensions of telephone lines must be routed through public right-of-way, which substantially increases the access distance in some cases.

Table 9 lists the total capital costs for the sites in question. Some of the equipment at the U. S. Commlink sites was not necessary for this subtest. To give an idea of what smart call box traffic census systems might cost by themselves, Table 10 lists site costs including only weather detection and reporting equipment.

Table 10. Site Costs for Hazardous Weather Reporting Alone.

Site	Cost, Hazardous Weather Reporting Only
USCL-1	$4,900
USCL-5	$2,815
GTE-4	$4,900
GTE-5	$4,900

Operating Costs

Operating costs include telephone charges and maintenance costs. Current telephone charges paid by Caltrans for conventional telephone service and San Diego SAFE for cellular service are $14.00 per month per line for conventional service and $10.00 per month per line for cellular service. This means that the test systems actually have a slight advantage in terms of telephone charges in the San Diego area, although this may not be true elsewhere.

Although determination of maintenance costs for smart call box systems was a major goal of the FOT evaluation as initially conceived, the data collected are not adequate for this purpose. In the case of this subtest, system reliability appears to have been high once system bugs were worked out, so that maintenance costs should be reasonably low. It should be recognized, however, that maintenance costs may depend heavily on certain institutional decisions, particularly that of whether maintenance is to be done by the vendors under contract or in-house by public agencies.

Life-Cycle Costs

Given that capital costs vary widely depending on site conditions (particularly access distances to hardwire telephone systems) and that maintenance costs for the test systems are uncertain, it is not possible to determine exact life cycle costs for the test systems or to compare them with those of the baseline system. A more reasonable approach is to determine the break-even points between the test and baseline systems, based on telephone access distances, differences in maintenance costs, and differences in assumptions about interest rates. Table 11 gives the maximum additional maintenance cost per unit for the smart call box system at break-even, as a function of the access distance for conventional telephone and the assumed interest rate.

All calculations are based on an assumed life of 10 years with no salvage value, and the monthly telephone charges listed in the section on “Operating Costs.” In addition, all calculations assume that for the baseline system both trenching and cabling is required for the full access distance listed, but that there are no additional costs in providing hardwire connections, such as jacking conduits under traffic lanes. Trenching casts are assumed to be $10.00 per foot, and cabling costs to be an additional $1.00 per foot, for a total of $11.00 per foot. These cost assumptions are based on estimates by Caltrans.

For the sites involved in this subtest, telephone access distances for the baseline system varied from 1,600 ft to 8,500 ft, with the median distance being around 4,500 ft. Thus for sites typical of the subtest, smart call box systems are likely to have a cost advantage over conventional systems so long as the difference in annual maintenance costs does not exceed about $7,500 per unit. As maintenance costs this high are unlikely, given the apparent reliability of the systems, life cycle costs of smart call boxes will probably be less than those of hardwire systems at most sites.

Table 11. Break-Even Maintenance Cost Differences for Smart Call Boxes with Weather Sensors.

Access Distance for Baseline System, Ft.	Max. Difference in Annual Maintenance Costs (Call Box - Baseline) for Given Interest Rate		
	5%	7.5%	10%
100	$333	$369	$406
200	$475	$529	$585
500	$903	$1,010	$1,122
1,000	$1,615	$1,811	$2,018
2,000	$3,039	$3,414	$3,809
5,000	$7,313	$8,222	$9,181
10,000	$14,435	$16,235	$18,135

CONCLUSIONS

This section of this report documents the evaluation of the Hazardous Weather Detection and Reporting Subtest of the Smart Call Box FOT. Objectives of the evaluation were to determine the cost-effectiveness of using smart call boxes for the processing and transmission of hazardous weather alarms. This included assessing the effectiveness of the various test systems, estimating life cycle costs, and identifying tradeoffs among the baseline system and the various test systems. In addition, the subtest evaluation addressed issues such as potential improvements to the designs tested in the FOT and actions related to specific test systems that should be undertaken prior to deployment. A more general discussion of actions required before deployment may be found in the subtest report on Institutional Issues. Major conclusions include:

1. The GTE low visibility system and the U. S. Commlink Davis weather station systems were adequate in terms of their basic functionality. The functionality of the U. S. Commlink low visibility system could not be verified because there were no low-visibility incidents during its period of operation.

2. System reliability, as measured by system availability, was adequate for the GTE low visibility system. That of the U. S. Commlink Davis weather station was adequate during the short period the system was operational; however, the FOT did not provide enough experience with this system to allow conclusions about its long-term reliability. The reliability of the U. S. Commlink low visibility system is unknown, since its functionality was never verified under field conditions.

3. Capital costs of the systems tested here are about $5,000 for the low-visibility systems and $3,000 for the U. S. Commlink Davis weather station system. None of these systems requires an external power supply.

4. The cost-effectiveness of the various test systems, when compared with the baseline system, depends on access distances to the hardwire telephone system and maintenance costs for the smart call box systems. Since maintenance costs for the test systems could not be determined, these break-even points between the test systems and the baseline system may be stated in terms of differences in maintenance cost. For telephone access distances typical of the FOT, break-even annual maintenance cost differences are on the order of $7,500 per unit.

5. Prior to deployment, continued testing should be undertaken to establish the reliability and maintenance costs of the U. S. Commlink systems involved in this subtest. Also, prior to deployment of the low-visibility detection system, it would be desirable to develop a sensor network involving multiple locations and a well-thought out response strategy, detailing how agencies involved in management of low-visibility incidents are to respond.

6. Design enhancements that would improve the utility of the test systems include 1) provision of multiple alarm levels and all-clear indications, 2) modification of the GTE system to incorporate sensor verification capability and the ability to download sensor data, 3) transmission of character strings rather than FAX messages, and 4) development of software to record and display alarms at the TMC.

The subtest also provided several important lessons related to technology, system design concepts, the design process, and the process of testing and evaluating the systems. These included:

1. Most of the data processing for the systems involved in this subtest took place in the sensors, with the call boxes serving primarily as a data communications link. This precluded remote reprogramming of alarm thresholds. This is not a major problem, however, because thresholds are not changed very often. The call box microprocessor card was essential, however, because it was used to generate alarm messages.

2. In the case of the low-visibility warning system, there may be need for more than isolated warning devices. Rather, what may be required is a carefully designed network of alarm stations which can provide advance warning of the approach of fog.

3. Integration of alarms into TMC operations needs careful consideration. In particular, consideration needs to be given 1) to determining the best way to provide an alarm that will get the TMC operators' attention, and 2) providing software to record alarms and display the type and location of the weather condition involved. Also, consideration needs to be given to the fact that hazardous weather conditions occur at times when TMCs are not normally staffed, such as late at night.

4. In the selection of weather sensors, there may be a tradeoff between cost and accuracy. This issue was not confronted directly in the FOT because the planned test by U. S. Commlink of a system incorporating a Vaisala weather station was canceled. As originally planned, the U. S. Commlink portion of the subtest would have compared systems incorporating a low-cost weather station (the Davis) with one involving a more expensive but more accurate unit (the Vaisala). Careful consideration needs to be given to the level of accuracy required for traffic-related weather alarms before systems involving high-end weather stations are developed.

5. The evaluation of the systems involved in this subtest was hampered by inability to confirm weather conditions in more than a general way. In the case of the low-visibility alarm systems, it had originally been planned to provide verification by means of a CCTV system. This could have allowed verification of the alarms that were actually received; however, there was never any practical way to eliminate the possibility that sensors were failing to respond to conditions that warranted alarms. As it turned out, even verification of the conditions associated with the alarms was not possible, due to schedule slippage and lack of coordination with the CCTV subtest.

CHANGEABLE MESSAGE SIGN CONTROL SUBTEST

SUBTEST OBJECTIVES

The objective of this subtest was to evaluate the cost-effectiveness of smart call boxes for controlling CMSs. This included determining the following:

- The relative effectiveness of several different test systems involving use of smart call boxes to control CMSs when compared with one another and with a baseline system consisting of control of CMSs by hard-wire telephone. Effectiveness was defined to include the functional adequacy, accuracy, and reliability of the data processing and data transmission provided.

- The projected life-cycle costs of the different test systems and the baseline system.

- Tradeoffs (if any) between use of the various smart call box systems and hard-wire telephone systems to control CMSs.

SUBTEST DESCRIPTION

As envisioned in the FOT's Request for Participation (RFP), the CMS Control Subtest was to have been linked to the Hazardous Weather Detection and Reporting Subtest and, possibly, to the Incident Detection Subtest. The overall test was to have demonstrated the ability of smart call boxes to determine alarm conditions, select preprogrammed warning messages, and transmit these messages to other call boxes serving as controllers for CMSs displaying the messages. The key feature of the CMS portion of the test was to be the use of the call box as a replacement for the hardwire communications system and Model 170 traffic controllers currently used for CMS control in California. The test was to have involved systems developed by two different vendors, each of which was to control two CMSs.

In the process of developing the test system design, it was discovered that 1) the Caltrans District 11 Transportation Management Center (TMC) was not receptive to the idea of automatically-controlled CMSs; 2) the Model 500 CMS used by Caltrans was not designed in such a way that a call box could easily replace the Model 170 controller; and 3) systems already exist in which cellular telephone communications are integrated with Model 170 controllers. In light of these developments, the RCT decided on March 1, 1996 to terminate the subtest prior to installation of equipment in the field.

SUBTEST CHRONOLOGY

Development of Performance Standards and Specifications

As envisioned in the Evaluation Plan, development of performance standards, specifications, and test system designs were to have been distinct phases in the development of test systems. Performance standards were to have been determined by Caltrans District 11 (as the "customer"). The Project Manager was to refine these into specific functional specifications, which would in turn be used by the vendors to develop detailed specifications and designs.

In practice, however, there was a great deal of overlap between the development of standards, specifications, and system designs, with formal performance standards being adopted late in the process and continuing to evolve thereafter. In the case of the CMS Control Subtest, moreover, there were late changes in the overall concept of the test that affected the specifications.

The original FOT Proposal of October 1992 called for a system in which alarms from the Incident Detection Subtest would be transmitted to the Caltrans TMC and messages in response would be transmitted back from the TMC to CMSs via call boxes. The messages were to include both "canned" and event-specific messages. Eight sites to be used, and some of these were to be new installations where signs would not be installed without remote communications capability. Shortly after the FOT was funded, the Work Plan was revised in October 1993 to reduce the number of sites to four.

In the period between October 1993 and July 1994, the RCT discussed the issue of whether the CMS subtest was to be completely independent test or to be coordinated with the Hazardous Weather and Incident Detection subtests. It was felt that use of CMSs to inform motorists of hazardous weather conditions or incidents was a logical extension of the other subtests, and that it might even be possible to have canned CMS messages triggered by weather or incident alarms. It was not clear that this would be feasible, however, or that it would be acceptable to Caltrans operations personnel.

On July 27, 1994, the initial draft of the project RFP was released at a meeting of prospective vendors. This draft RFP stated that call boxes were to be connected to existing CMSs at four sites selected by Caltrans to support the Hazardous Weather and Incident Detection subtests. At a minimum, these call boxes were to function as remote terminals and to transmit display assignments as determined by Caltrans. The draft RFP further stated that transmissions by call boxes to CMSs were to be effected using low-power RF transmissions or as proposed by the vendor. The final version of the RFP was issued on August 15 with no revisions to the section dealing with this subtest.

Up to this point, there had been no discussions with District 11 TMC personnel about their requirements for any of the subtests, nor were there any formal performance standards. On August 25, the Evaluator met with various members of Caltrans District 11 operations staff to discuss performance standards. At this meeting, Caltrans TMC personnel stated that they did not intend to use "canned" messages; rather, all messages would be prepared by TMC personnel. They believed that preprogrammed messages would not provide adequate flexibility in communicating with the public. They stated that typical CMS messages involve too many variables (location of the problem, details of the traffic situation, etc.) to be determined in advance; consequently, they would rarely post the same message more than once. They also stressed that test systems should be compatible with the Signview software used to control the existing CMSs and should be capable of transmitting existing message verification signals, which involved verification switch positions rather than actual message displays. Finally, they raised the issue of message security, and suggested that dynamic encryption might be required. Formal performance standards were finally issued on October 18. These standards are documented in Appendix D.

Meanwhile, in the course of preparing proposals, one of the vendors raised questions concerning information flow and provision of equipment for data collection. On October 7, representatives of the Project Manager, the Evaluator, and Caltrans met to discuss these issues. As a result of this meeting, schematic diagrams showing information flow for each subtest were prepared and distributed to the vendors as an addendum to the RFP. In the case of the CMS Control Subtest, the diagram showed CMS control signals originating from the TMC; message verification signals (and video images of the CMS produced by the CCTV subtest) were to be routed directly to the TMC and subsequently passed on to the Project Manager.

Over the next several months, the vendors developed their final proposals, entered into contracts with the RCT, and began the actual design of test systems. Because the CMS subtest was scheduled for the last of three subphases of the FOT, little serious attention was paid to it until late 1995. At some point during this period, however, a major change occurred in assumptions about the way in which it was to be conducted, and this led to revised specifications. By August 1995, the idea of having CMSs controlled directly by the TMC had been dropped in favor of having all FOT functions controlled from a data collection center at the Project Manager's headquarters. This led to discussions about how the TMC could preempt control of signs during the test if this should be necessary.

Discussions within the Caltrans District 11 staff and between Caltrans, the Project Manager, and the vendors took place over the course of several months, during which time one of the vendors, U. S. Commlink, was also seriously investigating design requirements for the subtest. One suggestion was that by using Model 170E controllers for the signs, it might be possible to have a dual control system in which the TMC could preempt control unilaterally. Draft procedures for conducting the subtest were finally issued by Caltrans at the January 11, 1996 TAC meeting. These proposed a procedure for conducting the tests and transferring control to the TMC, assuming dual control was not available, but stated that less rigid procedures might be established if vendors could provide dual control.

Development of Test System Designs

GTE System

GTE's initial proposal was to provide two units for the CMS Control subtest. These were to use a TRW spread-spectrum RF transmitter/receiver to communicate between the call box and the CMS. The TMC would contact the call box by paging it. Upon receiving the page, the call box would power up and be available to be called by the TMC. Message verification would be by checksum comparison and by a video camera installed as part of the CCTV Surveillance subtest. GTE also stated that it would like to experiment with using the spread spectrum technology to transmit directly to vehicles, although this was recognized as being beyond the scope of the FOT.

In its response to the initial proposals, the RCT stated that use of spread spectrum radio was interesting but outside the scope described in the RFP. GTE was instructed to consider a serial connection to the CMS and to propose spread spectrum as an option, but with separately-identified cost. In its revised proposal of November 22, GTE listed specific sites for this subtest and stated that systems involving direct spread spectrum communications with vehicles were excluded.

On December 21, face-to-face negotiations were carried out between GTE and the RCT. As a result of these negotiations, GTE was instructed to propose the spread spectrum connection as an option; however, this option was later dropped. On January 23, 1995, a working group of the RCT met to recommend cuts in proposed test activities in order to bring them in line with the FOT budget. As a result of this meeting, GTE was instructed to provide two units for this subtest, which it agreed to do. In its reply of February 6, GTE proposed that both sites be shared with all other subtests.

A contract between the RCT and GTE was executed on June 26, 1995. At a TAC meeting on June 28, GTE distributed revised site configurations and a tentative installation schedule. Contrary to what had been proposed in February, most sites were now to be used for only one subtest. As before, two CMS sites were proposed, one of which was to be shared with the Incident Detection subtest. Once again, specific sites were listed. A meeting between Caltrans and GTE to review the sites was held on July 5; GTE received Caltrans' input at this meeting and issued the final list of sites in early September.

From this point until the cancellation of the subtest on March 1, 1996, GTE was largely concerned with development and testing of systems for other subtests. Consequently, GTE performed little additional system design work for this subtest.

U. S. Commlink System

U. S. Commlink's initial proposal included test sites in both San Diego County and the San Francisco Bay Area. For each location, a single freeway corridor would be instrumented, with multiple use of sites among the subtests. No specific number of sites was proposed for the CMS Control subtest. The subtest was to be conducted in two phases: Phase 1 would involve use of CCTV to verify CMS messages; in phase 2, call boxes would be used to control the CMSs. No details of proposed test system configurations were given; rather, there was a statement that plans and specifications would be developed after U. S. Commlink was given notice to proceed. The RCT opposed the use of test sites in the San Francisco Bay Area as being outside the scope of the FOT, but otherwise raised no questions about this subtest in its response to the initial proposals.

In its November 22 reply to the RCT's questions U. S. Commlink defended the idea of a Northern California portion of the FOT; however, this was not agreed to by the RCT, and the idea was dropped after the December 21 negotiations. On January 10, 1995, U. S. Commlink responded to the RCT's summary of the December 21 negotiations by submitting a schematic diagram of its new proposed test configuration. This diagram indicated that two units would be provided for the CMS Control Subtest. One of these would also be used in the Traffic Census subtest. The other, which would require A/C power, would also be used in the CCTV Surveillance subtest.

Following the meeting of the RCT working group on January 23, 1995 and the subsequent meeting of the full RCT on February 1, U. S. Commlink was asked to provide two units. On February 17, U. S. Commlink responded by proposing to provide the two units, both of which would also be used in the Traffic Census subtest, and one of which would also be used in the CCTV Surveillance subtest.

A contract between the RCT and U. S. Commlink was executed on April 6, 1995. At a TAC meeting on May 10, U. S. Commlink distributed a set of "site descriptions" detailing site requirements and equipment to be installed at each site, but did not list specific sites. Following two meetings with personnel from Caltrans, specific sites were designated and presented to the RCT at its June 7 meeting. Subsequent to this, U. S. Commlink announced that it would be modifying the microprocessor card used in its call box units, and that it would be undertaking extensive bench testing of the proposed test systems. On October 20, a demonstration was held at U. S. Commlink headquarters, in which a number of test system capabilities were demonstrated. This demonstration did not include CMS control, however.

U. S. Commlink did subsequently undertake a serious investigation of the issues involved in design of a CMS control system. As a result of this work, it became apparent that the CMS design used in California was not compatible with direct control by a smart call box. Rather, the Model 170 controller would have to be retained, and the call box could function only as a communications link. In was partly as a result of this information that the RCT ultimately decided to cancel the subtest.

Termination of the Subtest

In August 1995 the RCT became concerned about schedule slippage and its potential effect of FOT evaluation. A schedule revision was issued that called for the CMS Control Subtest to remain in the last subphase of the FOT, with a target date of March 1, 1996 for installation of equipment.

During the next several months, the schedule continued to slip due to the vendors' difficulties in getting equipment for Subphase 1 fully functional. By early January 1996, the RCT became seriously concerned that the FOT might not be completed on schedule. At its January 4, 1996 meeting, the RCT decided to have San Diego SAFE send both vendors notices to cure default.

The notices were distributed at the January 11 TAC meeting, along with a schedule revision establishing "firm" dates by which data collection was to begin. In the case of the CMS Control Subtest, the deadline was March 15. Following negotiations with the Project Manager, both vendors agreed to the March 15 date.

By March 1, however, there was no evidence that this deadline would be met. Meanwhile, the Project manager had informed the RCT that it had been seriously overspending its budget since November because coordination with the vendors had required much more time than had been anticipated. With both time and money constraints in mind, the Project Manager reviewed the remaining FOT tasks to determine whether some should be eliminated to save time and money. Based on this review, the Project Manager recommended that the CMS Control Subtest be terminated. This decision was based on a number of considerations:

1. At the time of the issuance of the RFP, the CMS Control Subtest been intended to test communications between one call box equipped with sensors and another controlling a CMS. It had been assumed that automatically-posted CMS messages (in response to a hazardous weather alarm, for instance) would be acceptable and that the CMS could be controlled from a call box. Establishment of the performance standards, however, had shown that the Caltrans TMC wanted to retain control over CMS operation, and that automatically-posted messages would not be a part of the field test.

2. In the course of U. S. Commlink's design investigations, it was discovered that the Model 500 CMS lacked the internal capability to switch the lights used to form the message. Rather, this function was performed by an external controller, such as the Model 170 traffic controller, which had to be connected to the sign by means of a large number of conductors. The overall system involved a program running on a computer at the TMC that generated on/off signals for the pixels in the sign, a hardwire telephone line to transmit these signals, and the Model 170 controller, which switched the lights on and off. Since the switching had to be done external to the sign, the controller had to have the capacity for a large number of conductor connections.

Since the call boxes lacked this capability, their only possible use was as a straightforward cellular telephone link, eliminating the existing hardwire link.

3. During the design phase of the Subtest, it was also discovered that Caltrans had independently acquired the ability to use cellular telephone links with Model 170 Controllers and had already used these to display CMS messages.

On March 1, after reviewing the Project Manager's recommendations, the RCT agreed that further pursuit of the CMS Control Subtest would serve no useful purpose and ordered that it be terminated.

CONCLUSIONS

Major lessons learned from this aborted subtest include the following:

1. Automatic control of CMSs is not currently acceptable to TMC personnel in the San Diego area. Their objections center around the complexity and variability of the messages that need to be posted by CMSs. They believe that the number of variables involved is too great to allow use of simple preprogrammed messages. Rather, sophisticated expert systems (which do not currently exist) are required, and even these will not be effective unless deployed in connection with a comprehensive set of signs and instrumentation and supported by adequate maintenance staffing. Operational personnel in other regions may be more receptive to automatically-controlled CMSs; however, it should not be assumed that the value of such systems will be obvious to them. Any future experimentation with automated CMSs should be carried out in conjunction with design of comprehensive motorist information systems, not as a side-issue in an equipment development effort.

2. The Model 500 CMS currently used by Caltrans is not suitable for control by smart call boxes. The type of system envisioned in the FOT proposal would have involved a sign with a built-in processor capable of accepting a text string, converting this to a bit map, and switching the lights in the CMS. The actual design of the Model 500 CMS requires an external controller to switch the lights and a complicated wiring system connecting the controller to the sign. Existing software generates a bit map for the sign from a remote location, which means that any system using smart call boxes to control CMSs will require not only a different design for the sign but also a different type of software.

3. Even with CMS designs involving internal controllers, there is no real need for any features of the smart call box system other than the cellular telephone. Since posting CMS messages requires software at the TMC in any case, the obvious architecture is to have the TMC software generate the bit map, as is the case with the existing software. Even if messages are to be posted automatically in response to alarms, the alarms will normally be transmitted to the TMC, and any processing needed to select the message can take place there. Consequently, all that is needed in the field is a

communications link and a controller capable of setting a large number of switches. Since this is so, there is no reason to use smart call boxes for CMS control, regardless of the design of the CMS.

4. Remote control of CMSs using cellular telephone units integrated with Model 170 controllers is feasible and has been demonstrated independently. It is beyond the scope of the FOT to determine whether such systems are cost-effective. It should also be possible to use cellular telephone units to communicate with internally-controlled CMSs; however, it is not known whether this has been demonstrated yet.

CCTV SURVEILLANCE SUBTEST

SUBTEST OBJECTIVES

The objective of this subtest was to evaluate the cost-effectiveness of using smart call boxes to control video cameras and transmit video signals. This included determining the following:

- The relative effectiveness of several different test systems involving use of smart call boxes to control video cameras and transmit video signals. For this subtest, there was no locally available baseline system for comparison. Effectiveness was defined to include the functional adequacy, accuracy, and reliability of the data processing and data transmission provided.

- The projected life-cycle costs of different test systems involving smart call boxes used to control video cameras and transmit video signals, as compared to one another.

- Tradeoffs (if any) between use of the various smart call box systems for the control of video cameras and transmission of video signals.

SUBTEST DESCRIPTION

Three smart call box units were tested. These involved two different test system configurations developed by the vendor team led by U. S. Commlink. Two of these involved monochrome systems and the third was a color system. One monochrome unit was installed at a site that was also used for the Traffic Census and Hazardous Weather Reporting subtests, and was intended to be used to verify visibility conditions. The other monochrome unit was located at a site that was also used for the Traffic Census subtest, and was intended to verify displays on a CMS. The color unit was located at a site that was used for the Traffic Census and Incident Detection subtests, and was intended to verify traffic conditions. In this case, the camera unit had PTZ capabilities, but these could not be controlled remotely through the smart call box. The vendor team led by GTE had also intended to test CCTV units, but this portion of the subtest was canceled by the RCT because the equipment could not be installed in time to permit evaluation. Appendix B documents overall system configurations for the two vendor teams, showing the units used in each subtest.

Field units for this subtest consisted of video cameras and video compression units. Compressed video signals were transmitted via the call boxes to the data collection center at the Project Manager's headquarters. Both test systems integrated call boxes with existing video cameras and compression units. Digitization and compression of signals was carried out by the video compression units, and the call boxes served primarily as communication links to transmit the compressed video signals and commands to turn the cameras on and off.

The following is a detailed description of the sites and equipment included in each test system. Block diagrams showing the functioning of these systems are presented in Appendix C.

U. S. Commlink Systems

- ***System Configuration 1: Monochrome FFOV***

  Equipment:

  1 - U. S. Commlink, Smart Card System
  1 - Cubic Call Box Assembly
  1 - Call Box Mounting Assembly
  1 - Cohu FFOV-B/W CCTV Camera
  1 - Odetics Fast Trans 2000 Video Modem 5, Distance Marker Placards
  1- Solar Charging System

  Sites:

  - I-5, Post Mile NB 36.826, Call Box Number 5-368, North of Via de la Valle. U. S. Commlink Site # 1
  - SR-163, Post Mile NB 5.498, Call Box Number 163-52, at Kearny Pedestrian Overcrossing. U. S. Commlink Site # 4.

- ***System Configuration 2: Color FFOV***

  Equipment:

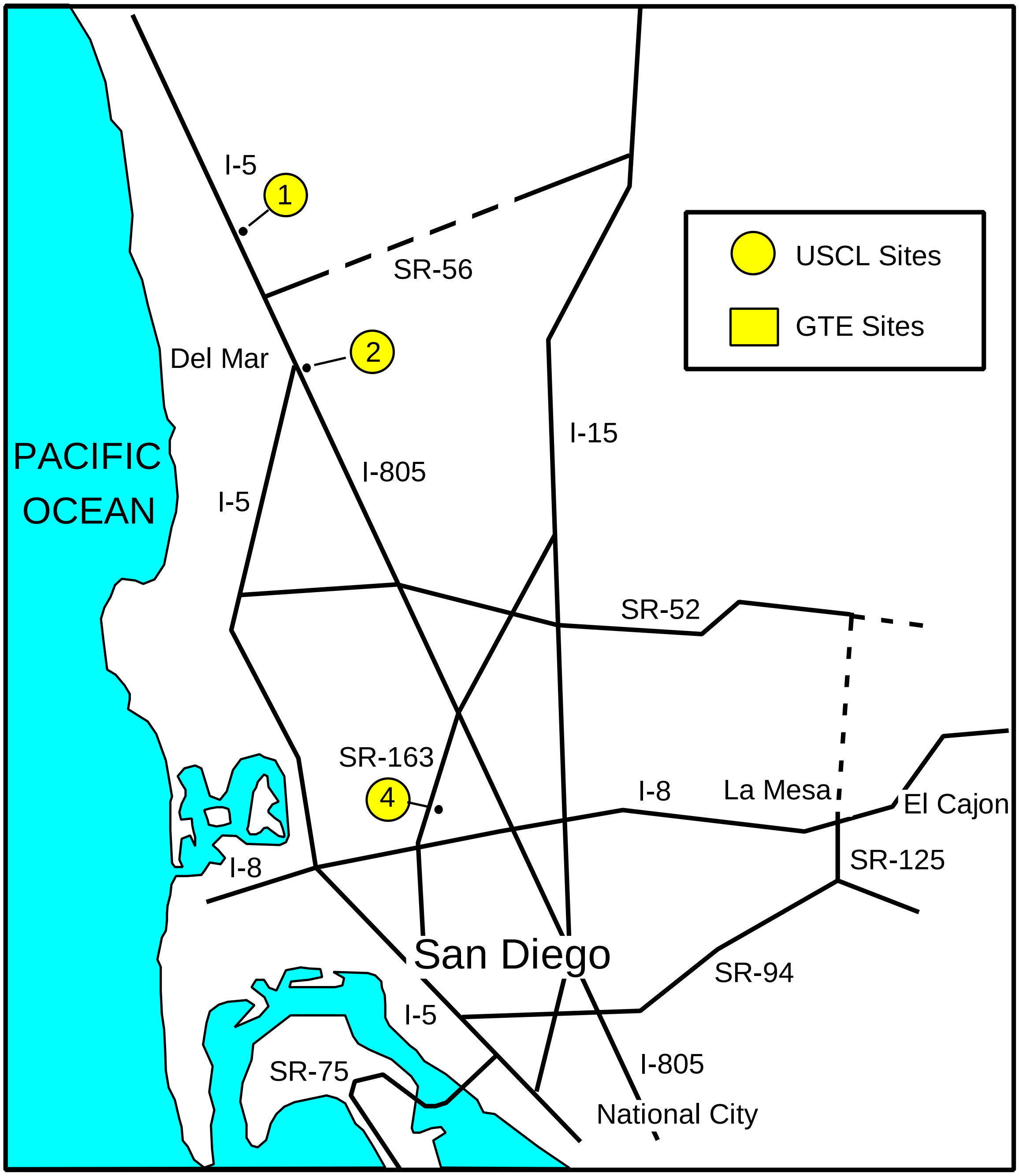
  1 - U. S. Commlink, Smart Card System
  1 - Cubic Call Box Assembly
  1 - Call Box Mounting Assembly
  1 - Cohu PTZ (color) CCTV Camera
  1 - Odetics Fast Trans 2000 Video Modem
  1- Solar Charging System

  Site:

  - I-5/I-805, Post Mile NB 805 28.526, Call Box Number 805-288, at I-5/I-805 Interchange. U. S. Commlink Site # 4.

Figure 8 is a map showing the location of these sites.

Figure 8. Map Showing Test System Sites for the CCTV Surveillance Subtest.



Data Transmission and Processing Tasks

All test systems were required to be capable of transmitting video signals and control messages to turn FFOV cameras on and off. Video signal transmission was required to provide for slow-scan video or better. All systems actually tested provided slow-scan video. These requirements are detailed in the subtest system Performance Standards in Appendix D.

SUBTEST CHRONOLOGY

Development of Performance Standards and Specifications

As envisioned in the Evaluation Plan, development of performance standards, specifications, and test system designs were to have been distinct phases in the development of test systems. Performance standards were to have been determined by Caltrans District 11 (as the "customer"). The Project Manager was to refine these into specific functional specifications, which would in turn be used by the vendors to develop detailed specifications and designs.

In practice, however, there was a great deal of overlap between the development of standards, specifications, and system designs, with formal performance standards being adopted late in the process and continuing to evolve thereafter.

In the case of the CCTV Surveillance subtest, the FOT proposal of October 1992 called for sixteen sites. Six of these were to be equipped with FFOV cameras that would be used for verification of Changeable Message Sign (CMS) displays and limited visibility conditions. Ten sites would be equipped with pan-tilt-zoom (PTZ) cameras that would be used to verify traffic incidents. FFOV cameras were expected to be mounted on traditional call box poles, and PTZ cameras on higher poles of some type. It was expected that PTZ cameras would require A/C current to operate. In October 1993, shortly after the FOT was funded, the Work Plan was revised to reduce the proposed number of sites for this subtest to ten.

On July 27, 1994 the initial draft of the project Request for Participation (RFP) was released at a meeting of prospective vendors. This draft RFP called for ten CCTV units. Call boxes were to be configured with one or more video cameras. The draft RFP stated that the CCTV installations would support nearby CMSs at sites pre-selected by Caltrans. Call boxes were to function as remote terminals to activate cameras to verify changes in traffic flow conditions, incidents, restricted visibility, and CMS displays. Minimum camera technology was to be slow-scan, real-time video (note: this was an error, as it is self - contradictory. The more correct specification would have been "slow-scan *or* real-time video," as it appeared in the FOT Proposal of October 1992). The RFP draft also stated that both single and stacked FFOV and PTZ cameras were of interest. There was no modification of this section in the final RFP of August 15.

A meeting between the Evaluator and various members of Caltrans District 11 operations staff was held on August 25 to discuss performance standards. At this meeting, it was decided that PTZ installations to be used for incident verification should provide continuous coverage of all lanes and shoulders in the vicinity of the camera. In addition, Caltrans operations staff stated that they wanted color images for incident verification, and that for this use image quality would have to be good enough to allow vehicle type and location to be distinguished. Systems used for incident verification would also need to be capable of sustained transmission of video signals for a period of at least five minutes. For installations involving CMS verification, it would have to be possible to read the CMS display. Later, some doubts were expressed as to whether color images would really be better than monochrome for incident verification, so that the Performance Standards as ultimately adopted only stated that color was "highly desirable".

Development of Test System Designs

Development of designs for the test systems was carried out by the vendors, with the scope of the test, as well as certain design details, subject to negotiation with the RCT. This process began with the vendors' preparation of proposals, which were submitted in late October 1994, and continued into field test portion of the project. In all cases, the test systems were designed by putting together preexisting components, so that the major design challenge was achieving end-to-end system integration. For the most part, this involved resolving software incompatibilities. In the case of this test, installation of field equipment did not take place until nearly the end of the data gathering phase of the FOT, so that there was little opportunity to verify that all software incompatibilities had really been eliminated. Since GTE's system design was not complete by the scheduled end of data gathering in mid-May 1996, the system was never installed. U. S. Commlink's systems were installed in early May. The color system at Site 2 continued operational at least until mid-June; however, the monochrome system failed at both sites in late May and had not been repaired by the end of data gathering in mid-June.

GTE System

GTE's initial proposal for the CCTV Surveillance subtest was to provide five units. Three of these were to be PTZ installations and two were to be FFOV. GTE proposed to use color, single-chip CCD cameras which would be capable of operation in low light conditions, and also use one monochrome camera for each type of location for purposes of comparison. Also, GTE proposed to install two separate master controllers for comparison. This proposal called for use of a paging system to contact the call box, which would then power up to receive a call from the TMC. Video control commands would be transmitted as RS-232 data packets; video signal transmissions would use a variable-rate compression system. The proposal stated that these configurations would require photo-voltaic power supplies about double the standard size used for call boxes in the San Diego area. In its response to the initial proposals, the RCT asked how the call box paging would be accomplished and whether there would be multiple FFOV cameras at a single site. In its revised proposal of November 22, GTE proposed specific sites for this subtest, stated that call box paging would employ a standard tone type commercial pager and that the paging process might take approximately one minute. The revised proposal did not clarify the question of whether there would be multiple FFOV cameras at a single site.

On December 21, 1994, face-to-face negotiations were carried out between GTE and the RCT. As a result of these negotiations, the RCT suggested the use of camera pre-sets for PTZ cameras. Also, GTE was instructed to consider location of call boxes outside the freeway clear recovery zone (due to traffic safety concerns), to implement the paging activation of the call boxes so that time delays were acceptable to TMC staff, and to advise the RCT on its proposed method for recording video signals for purposes of evaluation.

On January 23, 1995, a working group of the RCT met to recommend cuts in proposed test activities in order to bring then into line with the FOT budget. This meeting did not result in any proposed modifications for this subtest. On February 6, GTE proposed that two of the five units be FFOV units used with all the other subtests, and the other three be PTZ units which would be used with the Incident Detection subtest.

A contract between the RTC and GTE was executed on June 26, 1995. At a TAC meeting on June 28, RCT distributed revised site configurations and a tentative installation schedule. Contrary to what had been proposed on February 6, most sites were now to be used for only one subtest. As before, five CCTV sites were included. Once again, specific sites were proposed. A meeting between Caltrans and GTE to review the sites was held on July 5; GTE received Caltrans' input at this meeting and issued the final list of sites in early September.

U. S. Commlink Systems

U. S. Commlink's initial proposal included test sites in both San Diego County and the San Francisco Bay Area. For each location, a single freeway corridor would be instrumented, with multiple use of sites among the subtests. No specific number of sites was proposed for this subtest; however, the proposal seemed to imply that there would be two sites intended to verify low-visibility conditions and two additional sites to monitor traffic conditions and verify CMS displays. The U. S. Commlink team proposed to monitor traffic conditions with FFOV cameras and to test the capability of the call box to act as a controller for PTZ installations. No specific system configurations were described, although subcontractors and technical specifications for individual components were identified. The RCT opposed the use of test sites in the San Francisco Bay Area as being outside the scope of the FOT, and asked what parts of the proposed approach did not currently exist and when they would be ready for installation.

In its November 22 reply to the RCT's questions U. S. Commlink defended the idea of a Northern California portion of the FOT; however, this was not agreed to by the RCT, and the idea was dropped after the December 21 negotiations. U. S. Commlink also stated that the CCTV equipment necessary to implement its approach was available on the open market except that mounting brackets would have to be fabricated. It estimated that two to three weeks would be required for installation. Following the December 21 negotiations with the RCT, the RCT suggested the use of camera pre-sets for PTZ cameras and stated that PTZ cameras were desired in conjunction with the incident detection locations. Also, U. S. Commlink was instructed to consider location of call boxes outside the freeway clear recovery zone (due to traffic safety concerns), to provide costs for two FFOV and two PTZ locations, and to advise the RCT on its proposed method for recording video signals for purposes of evaluation. On January 10, 1995, U. S. Commlink responded by submitting a schematic diagram of its new proposed test configuration. This diagram indicated that four units would be provided. Each of these would be used in at least one other subtest and all would require A/C power.

Following the meeting of the RCT working group on January 23, 1995 and the subsequent meeting of the full RCT on February 1, U. S. Commlink was instructed to provide four units for this subtest. On February 17, U. S. Commlink responded by proposing to provide three units. Two of these would be FFOV units. One of these would also be used in the Hazardous Weather Reporting subtest and the other would be used in the CMS Control subtest. The third unit would be a PTZ unit which would also be used in the Incident Detection subtest. Of these, the FFOV unit used in the Hazardous Weather Reporting subtest and the PTZ unit would require A/C power.

A contract between the RCT and U. S. Commlink was executed on April 6, 1995. At a TAC meeting on May 10, U. S. Commlink distributed a set of “site descriptions” detailing site requirements and equipment to be installed at each site, but did not list specific sites. Following two meetings with personnel from Caltrans, specific sites were designated and presented to the RCT at its June 7 meeting. Subsequent to this, U. S. Commlink announced that it would be modifying the microprocessor card used in its call box units, and that it would be undertaking extensive bench testing of the proposed test systems. On October 20, a demonstration was held at U. S. Commlink headquarters, in which a number of test system capabilities were demonstrated, including transmission of monochrome FFOV video signals. This demonstration was attended by representatives of the RCT, the Project Manager, and the Evaluator.

Subtest Schedule Adjustments

In August 1995 the RCT became concerned about schedule slippage, and its potential effect on the evaluation of the FOT. A schedule revision was issued in which equipment installation for the CCTV Surveillance subtest was to be completed by March 1, 1996. During the next several months, the schedule continued to slip, due to the vendors’ difficulties in getting equipment for Subphase 1 fully functional. By early January 1996 the RCT once more became concerned that the FOT might not be completed on schedule. At the January 4, 1996 meeting of the RCT, the RCT decided to have San Diego SAFE send both vendors notices to cure default.

The notices were distributed at the January 11 TAC meeting, along with a schedule revision establishing “firm” dates by which data collection was to begin for each subtest. In the case of the CCTV Surveillance Subtest, the deadline was March 15. On January 26, U. S. Commlink informed the Project Manager that it could have equipment for the FFOV portion of the test installed by February 16, but not the PTZ portion. U. S. Commlink also stated that it could not meet deadlines for some of the other subtests.

Following this, the Project Manager was authorized to negotiate with the vendors to determine whether various portions of the FOT should be terminated or rescheduled. As a result of these negotiations, the RCT agreed to a schedule in which U. S. Commlink would drop the PTZ portion of the CCTV Surveillance Subtest and install the FFOV portion by March 15. Installation of GTE CCTV equipment was also scheduled for March 15, although the Project Manager noted that the GTE system was not yet working and that GTE was considering switching to a backup vendor.

As it turned out, neither vendor was able to meet the March 15 deadline. U. S. Commlink was able to finish designs for all three of its sites and install equipment by the beginning of May. Site 2, which was intended to provide verification of traffic conditions, had been planned as a PTZ installation. Use of an array of FFOV units had been suggested as an alternate as far back as the Draft RFP. When ordered to drop the PTZ portion, however, U. S. Commlink substituted a single color PTZ unit mounted on a 30-foot tower. This unit could be adjusted in the field; however, since there was no remote PTZ capability, the overall system functioned on a fixed-field-of-view basis. Test systems at the other two sites involved use of monochrome FFOV units mounted on the call box poles. These were partially concealed behind the solar panels to make them less conspicuous and thus less vulnerable to theft or vandalism.

Following the negotiations in January 1996, the GTE team continued to work on CCTV system designs but was unable to complete them in time to install equipment before the scheduled end of data gathering on May 15. On May 3, the RCT decided that it would cancel the GTE portion of the subtest if equipment had not been installed before the TAC meeting scheduled for May 9 (allowing less than a week for data gathering). When this deadline was not met, this portion of the subtest was canceled.

Installation of Test System Equipment

All U. S. Commlink FOT sites had been partially installed in November 1995 as a part of the Traffic Census subtest. CCTV equipment was installed at Sites 1, 2, and 4 during the week of April 29, 1996, and tested functional on May 3.

Conduct of Subtest

Since equipment installation for this subtest took place so near the scheduled end of data gathering, it was decided to extend the data-gathering period to mid-June. Equipment shakedown and data gathering for this subtest took place between May 3, 1996 and the termination of data gathering for the FOT on June 13.

The color system at Site 2 was located at one of the incident detection sites, and was intended to be used to verify traffic conditions. The monochrome system at Site 4 was intended to be used to verify the functioning of a CMS, and that at Site 1 had originally been intended to verify low visibility conditions. The initial test of the installation at Site 4 took place on May 7. At this point, picture quality was rather poor, but it was possible to read the CMS. Various test patterns were displayed. There were no problems in verifying fixed patterns. There were some problems in verifying flashing patterns, however, because the CCTV takes "snapshots" of the sign, and sometimes it was blank at the instant the camera was activated. In this case, however, it was determined that since the sign flash rate was not synchronized with the camera refresh rate, the pattern could eventually be verified.

On May 14, a demonstration of all three systems was held for representatives of the District 11 TMC. TMC personnel were reported that they were pleased with the quality of the images from Site 1 (which was focused on a set of paddles used to verify visibility at different ranges) but that they were disappointed with image quality at the other two sites. On May 23, all three systems were adjusted to improve image quality. On viewing videotapes of the resulting images, TMC personnel reported that they were pleased with image quality, particularly for the monochrome systems, but that they did not believe the color system would be useful for incident verification.

On May 29, the Project Manager had planned to conduct a night test at Site 4 to determine whether the system was capable of producing readable images of the CMS under low light conditions; however, before the test could be conducted, both monochrome systems failed. An attempt was made to correct these malfunctions on May 30, but it was unsuccessful, and neither site was operable at the end of data gathering on June 13. Meanwhile, on June 10, it was discovered that two of the visibility paddles at Site 1 had been hit by a vehicle and knocked down. Finally, in mid-July, the color system was used to verify that the incident detection system at the same site was sometimes failing to transmit alarms when traffic congestion was present.

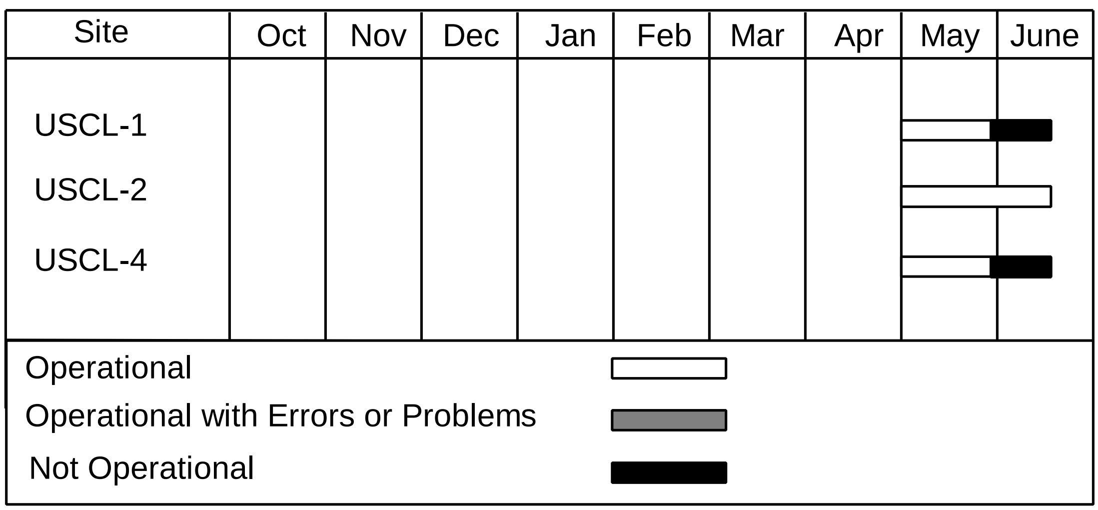
Figure 9 shows the periods during which the various CCTV surveillance test systems were operational.

ANALYSIS OF TEST SYSTEM EFFECTIVENESS

System Adequacy

The adequacy of the various test system designs was determined by comparing the final designs with performance standards established by the RCT and published in the FOT Evaluation Plan. In addition, test systems were reviewed for conformity to any other specifications established by the Project Manager in the Request for Participation (RFP) or promised by the vendors in their responses. Performance of system was evaluated by direct evaluation of image quality, and by having representatives of the Caltrans District 11 TMC review video image produced by the system and express their opinions of the systems' usefulness to them. Appendix E presents detailed comparisons of actual designs with performance standards and specifications related to the basic functionality of the test systems.

Figure 9. Operational Status of CCTV Surveillance Test Systems.



The system design for the monochrome fixed-field-of-vision CCTV system met or exceeded all standards. Initial image quality at Site 4 was marginal, but this improved after the system was adjusted. Also, it was noted that verification of flashing CMS messages sometimes failed due to the fact that the sign was blank when the camera was refreshing and that the limitation of this system to compressed video appears to make it inadequate for verification of scrolling CMS messages. Scrolling messages are not employed in California but may be used elsewhere.

The system design for the color CCTV system met or exceeded most standards; however, it had originally been intended that this be a PTZ system. Neither vendor was able to solve the communications problems involved in producing a remotely-controlled PTZ system. As a result, it did not meet the performance standard that called for continuous coverage of the roadway in the vicinity of the CCTV installation. The failure to provide remote PTZ control is a major practical issue. Without this capability, it is impractical to provide continuous coverage of a roadway with a CCTV system made up entirely of smart call box units. Initial image quality for this system was marginal, but improved after adjustment.

System Reliability

The two monochrome installations failed within a month of installation and had not been repaired by the end of data gathering. Since the cause of this failure was never determined, it is not possible to say whether it resulted from a design flaw which can be permanently corrected or a problem that might occur in a deployed system. The color system functioned without failures for approximately six weeks. In this case, however, the test was too short to draw conclusions about the system's long-term reliability.

COMPARISON OF TEST AND BASELINE SYSTEMS

System Adequacy

In the case of this subtest, there was no comparable baseline system in the San Diego area, although such systems exist elsewhere. The monochrome system appears to be as effective as real-time hardwire systems for the uses tested here, except that it appears to be inadequate for verification of scrolling CMS messages. Also, in the case of flashing CMS messages, the verification with the test system may take longer than with real-time CCTV, since several frames may be required. The color system does not appear to be as effective for verification of traffic conditions as a real-time video system. The most important limitation is the inability to control the camera remotely. As it result of this, it is unlikely that complete coverage of the roadway can be provided by smart call boxes. Also, even with reasonable image quality, the effect is more that of viewing a series of still pictures at intervals of about 8 to 40 seconds, depending on image size (the smaller the image on the screen, the faster the refresh rate). This means there is no real sense of motion conveyed by the video images; however, it is possible to identify vehicles (although it was sometimes difficult to verify whether the same vehicle was present in more than one frame), and it probably would be possible to identify an incident within the range of the camera.

System Reliability

The reliability of the test systems involved in this subtest is questionable. In the case of the monochrome system there was a system failure which had not yet been diagnosed by the end of the FOT. In the case of the color system, there were no failures, but the period of observation was too short to draw definite conclusions about its reliability.

ANALYSIS OF TEST AND BASELINE SYSTEM COSTS

Capital Costs

Test system costs include capital costs, maintenance costs, and the cost of cellular airtime. Capital costs were determined by having representatives of Caltrans District 11 structure bids for the installation of the test systems at the sites actually used, and then asking the vendors what they would bid for these items as a part of a full-scale deployment. Estimated capital costs for sites involved in the CCTV Surveillance Subtest are detailed in Appendix F. Since all these installations served more than one function, cost estimates include some items that were not related to the CCTV Surveillance Subtest.

Capital cost comparisons are summarized in Table 12.

Table 12. Capital Cost Comparisons for CCTV Surveillance Sites.

	Costs		Difference,
Site	Test System	Baseline System	Baseline-Test
USCL-1	$44,130	$77,480	$33,350
USCL-2	$57,800	$67,500	$9,700
USCL-4	$26,850	$28,300	$1,450

From Table 12, it may be seen that although capital costs are highly site-specific, the test system involves a substantial advantage in capital cost at two of the three test sites. This is primarily due to the high cost of trenching and installing telephone cables at these sites. In these cases, hardwire telephone infrastructure was not available in the immediate vicinity of the site, even though A/C power, which was required to operate the video cameras, was available. Under current Caltrans policy, moreover, any extensions of telephone lines must be routed through public right-of-way, and this substantially increases the access distance in some cases.

Table 12 lists the total capital costs for the sites in question. Some of the equipment at these sites was not necessary for this subtest. Also, costs at all sites were heavily influenced by the cost of providing A/C power, which vary widely depending on the characteristics of the site. To give an idea of what smart call box CCTV systems might cost by themselves, and the impact of the cost of external power supply costs, Table 13 lists site costs including only CCTV equipment, cost of external power supplies, and CCTV system costs exclusive of power costs.

Operating Costs

Operating costs include telephone charges and maintenance costs. Current telephone charges paid by Caltrans for conventional telephone service and San Diego SAFE for cellular service are $14.00 per month per line for conventional service and $10.00 per month per line for cellular service. This means that the test systems actually have a slight advantage in terms of telephone charges in the San Diego area, although this may not be true elsewhere.

Table 13. Site Costs for Traffic Census Alone.

Site	Cost, CCTV Surveillance Only	External Power Costs	Cost, Exclusive of External Power
USCL-1	$20,030	$15,000	$5,030
USCL-2	$35,900	$22,400	$13,500
USCL-4	$7,750	$3,850	$3,900

Although determination of maintenance costs for smart call box systems was a major goal of the FOT evaluation as initially conceived, the data collected are not adequate for this purpose. Also, it should be recognized that maintenance costs for deployed systems may depend heavily on certain institutional decisions, particularly that of whether maintenance is to be done by the vendors under contract or in-house by public agencies.

Life-Cycle Costs

Given that capital costs vary widely depending on site conditions (particularly access distances to hardwire telephone systems) and that maintenance costs for the test systems are uncertain, it is not possible to determine exact life cycle costs for the test systems or to compare them with those of the baseline system. A more reasonable approach is to determine the break-even points between the test and baseline systems, based on telephone access distances, differences in maintenance costs, and differences in assumptions about interest rates. Table 14 gives the maximum additional maintenance cost per unit for the smart call box system at break-even, as a function of the access distance for conventional telephone and the assumed interest rate.

All calculations are based on an assumed life of 10 years with no salvage value, and the monthly telephone charges listed in the section on "Operating Costs." In addition, all calculations assume that for the baseline system both trenching and cabling is required for the full access distance listed, but that there are no additional costs in providing hardwire connections, such as jacking conduits under traffic lanes. Trenching casts are assumed to be $10.00 per foot, and cabling costs to be an additional $1.00 per foot, for a total of $11.00 per foot; these cost assumptions are based on estimates by Caltrans.

For the sites involved in this subtest, telephone access distances for the baseline system varied from 300 ft to 3,250 ft, with the median distance being around 1,100 ft. Thus for sites typical of the subtest, smart call box systems are likely to have a cost advantage over conventional systems so long as the difference in maintenance costs does not exceed $1,500.

Table 14. Break-Even Maintenance Cost Differences for Smart Call Boxes with CCTV Units.

Access Distance for Baseline System, Ft.	Max. Difference in Annual Maintenance Costs (Call Box - Baseline) for Given Interest Rate		
	5%	7.5%	10%
100	- $120	- $141	- $164
200	$22	$19	$15
500	$449	$500	$553
1,000	$1,162	$1,301	$1,448
2,000	$2,586	$2,904	$3,239
5,000	$6,860	$7,712	$8,611
10,000	$13,982	$15,725	$17,565

CONCLUSIONS

This section of this report documents the evaluation of the CCTV Surveillance Subtest of the Smart Call Box FOT. Objectives of the evaluation were to determine the cost-effectiveness of using smart call boxes control video cameras and transmit video signals. This included assessing the effectiveness of the various test systems, estimating life cycle costs, and identifying tradeoffs among the baseline system and the various test systems. In addition, the subtest evaluation addressed issues such as potential improvements to the designs tested in this FOT and actions related to specific test systems that should be undertaken prior to deployment. A more general discussion of actions required before deployment may be found in the subtest report on Institutional Issues. Major conclusions include:

1. Both systems tested functioned adequately, however, lack of remote PTZ capability definitely limits the usefulness of smart call box CCTV systems for incident verification purposes. It is unlikely that such systems will be able to provide complete coverage of the roadway, although they may be useful for limited areas with high incident potential. Also, the refresh rates for the color system are too low to allow any sense of motion, which may also limit its usefulness.

2. System reliability, as measured by system availability, was inadequate for the monochrome system; however, this systems was not installed long enough for initial design flaws to be identified and eliminated. Reliability of the color system was adequate during the short period the system was operational; however, the FOT did not provide enough experience with this system to allow conclusions about its long-term reliability.

3. Capital costs of the systems tested here are expected to vary widely depending on the type of system, and the cost of supplying external A/C power, which is required for both systems. Overall costs for the monochrome system were on the order of $8,000 to $20,000, or about $4,000 to $5,000 exclusive of power supply costs. The overall cost of the color system was around $36,000, most of which was due to the cost of supplying A/C power to the test site; the cost of this system was about $13,500 exclusive of the external power supply cost.

4. The cost-effectiveness of the various test systems, when compared with the baseline system, depends on access distances to the hardwire telephone system and maintenance costs for the smart call box systems. Since maintenance costs for the test systems could not be determined, these break-even points between the test systems and the baseline system may be stated in terms of differences in maintenance cost. For telephone access distances typical of the FOT, break-even annual maintenance cost differences are on the order of $1,000 per unit.

5. The color system is probably not cost-effective when compared with the baseline system, except for special applications. This is due to the limited coverage of the roadway that it can provide, the slow refresh rate, and the lack of remote PTZ capability.

6. Prior to deployment, additional testing of the systems involved in this subtest should be carried out to establish reliability and maintenance costs.

7. Development of a version of the monochrome system that does not require external power would enhance the usefulness of this system. GTE attempted to develop such a system but was unable to install it in time for testing as a part of the FOT.

The subtest also provided several important lessons related to technology, system design concepts, the design process, and the process of testing and evaluating the systems. These included:

1. Real-time video transmissions and PTZ control are both beyond the current capabilities of smart call boxes.

2. System integration was a major design issue for the systems involved in this subtest. A standard communications protocol for compressed video systems that recognizes the requirements of wireless communications systems is highly desirable. It is questionable, however, whether the market for smart call box systems is large enough to support development of such a protocol. Any such protocol would form part of the National Transportation Communications for ITS Protocol (NTCIP) standards currently under development (*2*). In order to provide standards specifically adapted to smart call boxes, the current NTCIP effort will need to be extended to include standards for smart call box higher level interactions.

3. In developing systems similar to the ones tested in the FOT, it is wise to start with simple solutions and add enhancements later. It is rumored that one reason GTE was unable to meet the time constraints of the FOT was that it attempted an overly-ambitious design for this subtest.

4. The evaluation objectives of this subtest were based on the false assumption that system functionality would not be a major problem. In retrospect, the subtest evaluation should have focused on system functionality. Evaluation of reliability and maintenance requirements requires a much longer test, and should not have been undertaken until after basic functionality was well-established.

INSTITUTIONAL ISSUES

SUBTEST OBJECTIVES

The objective of this subtest was to evaluate institutional issues encountered in the Field Operational Test. This included determining the following:

- Whether any institutional issues encountered in the FOT have a potential for affecting the performance of smart call box systems if widely deployed.

- The perceptions of participants in the FOT regarding its administration, any other significant institutional issues encountered, and the effect of institutional issues on smart call box systems if widely deployed.

SUBTEST DESCRIPTION

The evaluation of institutional issues was based on information obtained from documentary sources, interviews with participants, and the experiences of the Evaluator as a participant in the FOT.

Project documents were reviewed to identify material in them pertaining to institutional issues. Such material was abstracted and used to identify issues. Documents reviewed included contracts and agreements, progress reports, project diaries, correspondence among participants, notes of meetings of the RCT and the TAC, and the evaluation documents. A list of documents reviewed is included as Appendix G.

Participants in the FOT were interviewed either in person or by telephone to determine their opinions about institutional issues. Interviews of local participants who were heavily involved in the FOT were conducted in person; those of out-of-town participants and local participants with less involvement were conducted by telephone. Typed summaries of interviews were prepared and mailed to the subjects, who were asked to review these summaries to verify their accuracy. A copy of the interview form is included as Appendix H. Appendix I is a list of the interviews conducted.

The interviews were intended primarily to assist in the identification of institutional issues, although there were also questions related to the potential impact of institutional issues on the outcome of the FOT and ways of overcoming institutional barriers to the deployment of smart call boxes. Since questions were open-ended, and there was considerable variation in the extent to which respondents had been involved in the FOT, responses tended to vary a great deal. For the most part, respondents mentioned issues that had already been identified through the review of project documents and the experiences of the Evaluator as a participant in the FOT.

Issues that were most frequently mentioned by survey respondents included the compatibility of test system designs with TMC needs, the possible impact of FOT procurement policies and business practices in the electronics industry on the quality of the test systems, issues related to ownership and financing of deployed smart call box systems, delays and other problems that resulted from the contracting procedures used to establish the FOT, issues related to the roles of the Project Manager and the vendors, and relationships between call box providers and data users.

In addition to its role in the identification of institutional issues, the survey of participants contributed in other ways to the analysis of issues. Several of the recommendations discussed in this report were suggested or confirmed by survey responses.

IDENTIFICATION OF INSTITUTIONAL ISSUES

Institutional issues were identified based on review of project documents, interviews with participants, and the experiences of the Evaluator as a participant in the FOT. The issues identified included those pertaining to the FOT itself and those likely be encountered in the deployment of smart call box systems. Some, but not all, of the issues encountered in the field test itself are likely to involved in the event of full-scale deployment. Appendix J presents a detailed list of issues that were identified. This list is classified according to whether the issue arose in the conduct of the FOT itself or is an additional issue which is expected to apply to deployment. Issues in this list were later regrouped for purposes of analysis; the major emphasis is on issues which might affect deployment, whether encountered in the FOT itself or not. Also, the analysis of issues presented in the next section omits some minor issues encountered in the conduct of the FOT that are not expected to affect deployment.

ANALYSIS OF INSTITUTIONAL ISSUES

Analysis of institutional issues consisted of preparation of detailed summaries for each issue that was considered significant. These include a description and discussion of the issue, an assessment of its seriousness, identification of the institutional participant(s) who raised it, a discussion of ways of avoiding or mitigating any problems identified, and, for issues related to system deployment, a list of actions required to resolve the issue in the event of deployment. These detailed issue summaries are presented in Appendix K.

Perhaps the most important issue related to the deployment of smart call box systems is that of whether the test systems produced as a part of the FOT really meet the needs of potential users. A common perception among participants in the FOT was that plans for using smart call box systems had not yet been worked out, and that questions remained as to what data will be collected, who will use it, and how it will be used. In addition, the process of developing specifications for the test systems may not have involved all the right people, and may not have resolved the conflicting ideas held by different types of participants. In particular, there were important differences in outlook between Caltrans operational personnel, who wanted conservative system designs tailored to needs they already recognized, and representatives of the RCT and the sponsoring agencies, who wanted more innovative designs which would be of wide applicability.

A second very important set of deployment-related issues concerns the basic concepts involved in the procurement, ownership, and financing of smart call box systems. The existing California call box system is highly privatized. It involves special-purpose county-level agencies (SAFEs) funded by a surcharge on vehicle registration fees that is imposed on a county-option basis. The SAFEs contract with a private consulting firm to manage the system and with private-sector vendors to provide, install, and maintain the call boxes. In most cases, SAFEs own the call boxes, although some are provided under lease-purchase agreements with the vendors. Outside California, very different arrangements may be considered.

Within California, provision of smart call box systems under the existing institutional arrangements poses problems, since the SAFEs are most likely to own the call boxes, but the data produced by them is expected to be used by Caltrans or various local agencies other than the SAFEs. Issues that need to be resolved include the willingness of individual SAFEs to accommodate smart call box features and the question of possible compensation by Caltrans or other data users for smart call box services provided by the SAFEs. Also, it is possible that California will experiment with a variety of institutional arrangements other than those currently used for the voice call box system.

From the point of view of potential vendors, the most important issue is whether the market for smart call box systems is large enough to permit them to make a reasonable profit. Representatives of the FOT vendors have expressed doubts about the potential profitability of some of the applications involved in the FOT. The lack of quantitative market research was a major omission in the FOT.

Other issues which could have a potentially serious impact on system deployment include possible organizational instability and cash flow problems in the electronics industry, disputes over intellectual property rights, the viability of systems involving more than one vendor in a particular geographical area, system maintenance issues, and concerns about the environmental and esthetic impact of certain system components. Other minor issues include assignment of risk for stolen or damaged equipment, requirements for encroachment permits issued by highway agencies, incorporation of call box data into other traffic data bases, and the possibility that current contracts between agencies providing call boxes and cellular carriers may not provide for data transmission.

The most important issues related to the conduct of the FOT itself involved the basic organization of the FOT and contracting procedures. Schedule slippage had a major impact on the outcome of the FOT, and much of this schedule slippage was due to time consumed in negotiating and processing contracts. Some of this delay was due to the extremely cumbersome procurement procedures of the State of California, and to the fact that Caltrans failed to process the separate FOT and evaluation contracts simultaneously. Much of the rest was due to the fact that the vendors and the RCT were involved in an arms-length relationship that involved issuance of a request for participation (RFP), preparation and evaluation of vendor proposals, and negotiation and processing of contracts between San Diego SAFE (acting as agent for the RCT) and the vendors. Several participants suggested that a more appropriate basic organizational model would have been to include the vendors (and the Project Manager) as partners in the original proposal. It was also suggested that participation by the Evaluator at the proposal stage would have been appropriate.

In addition, there was an issue as to whether the FOT should have been controlled locally or at the state level. This FOT was unique in California in that it was the only one where effective control of the FOT was maintained at the local level instead of being given to the Caltrans Office of New Technology and Research. Most participants indicated that they thought the local control of the FOT was one of its strengths, but at least one representative of the Office of New Technology and Research believes that local control weakened its technical accomplishments.

Less important issues related to the conduct of the FOT included the appropriateness of the evaluation guidelines provided by FHWA, communication between the RCT and the sponsoring agencies (or, more accurately, among the sponsoring agencies), and concerns about potential conflicts of interest involving the Project Manager.

CONCLUSION

The major hypothesis related to the analysis of institutional issues was that there are no insurmountable institutional barriers to the deployment of smart call box systems. This appears to be true, although a number of important questions related to deployment remain unresolved. The most important of these are the potential profitability of smart call box systems to potential vendors, the appropriateness of the designs produced as part of the FOT, and the appropriate models for procurement, ownership, and funding of smart call box systems. Important recommendations for overcoming potential institutional barriers to deployment include:

- Prospective vendors of smart call box systems should carry out additional market research to identify viable market niches for particular smart call box configurations. Vendors should also carry out additional technical development based on this market research, if the market research indicates that this is required.

- Agencies considering deployment of smart call box systems should plan deployment carefully. Deployment planning should resolve issues related to the basic procurement model (in-house or privatized), call box ownership, financing and compensation of agencies providing call box service, maintenance arrangements, data collection and distribution, potential environmental impacts and community concerns, permit requirements, contracts with cellular carriers, and incorporation of smart call box data into existing traffic databases.

- To whatever extent permitted by procurement regulations, agencies considering the deployment of smart call boxes should investigate the qualification of prospective vendors and give preference to those possessing adequate resources and displaying adequate commitment to the project. Issues to consider when investigating the qualifications of vendors include the financial health of the firm, the policies and level of commitment of the parent firm (if applicable), and the extent to which the vendor is dependent on subcontractors for key services needed to carry out the contract.

Additional detailed recommendations may be found in the issue summaries in Appendix K and the FOT Summary Report (*1*).

REFERENCES

1. Banks, J. H., and P. A. Powell. *Smart Call Box Field Operational Test Evaluation Summary Report*. PATH Report D96-33. California PATH Program, Richmond, California, 1996.

2. The NTCIP Steering Group. *National Transportation Communications for ITS Protocol (NTCIP), a Family of Protocols*. May, 1996. Available at World Wide Web Site http://fhwatml.com.

3. Payne, H. J., and S. C. Tignor. "Freeway Incident Detection Algorithm Based on Decision Trees with States." In *Transportation Research Record 682*, TRB, National Research Council, Washington, D. C., 1978, pp. 30-37.

4. Hall, F. L., Y. Shi, and G. Atala. "On-Line Testing of the McMaster Incident Detection Algorithm Under Recurrent Congestion." In *Transportation Research Record 1394*, TRB, National Research Council, Washington, D. C., 1993, pp. 1-7.

5. Chassiakos, A. P. and Y. S. Stephanedes. "Smoothing Algorithms for Incident Detection." In *Transportation Research Record 1394*, TRB, National Research Council, Washington, D. C., 1993, pp. 8-16.

APPENDIX A

VENDOR TEAMS

Team 1

Prime Contractor: GTE Telecommunications Systems, Inc.

Subcontractors:

Jaycor Corporation
TRW Avionics & Surveillance Group
icon networks
Gyyr Inc.

Team 2

Prime Contractor: U. S. Commlink

Subcontractors:

Ball Engineering Systems
CCS Planning and Engineering, Inc.
Coastal Environmental Systems
Cohu, Inc.
Davis Instruments
FPL and Associates, Inc.
icon networks
Jaycor Corporation
Lawrence Livermore National Laboratories
Gyyr Inc.
Peek Traffic, Inc.
Schwartz Electro-Optics, Inc.
Vaisala, Inc.

APPENDIX B

SITE CONFIGURATIONS

U. S. Commlink Test Sites.

Site No.	Site	Subtest			
		Traf. Cen.	Incid. Det.	Weather	CCTV
1	I-5, PM NB 36.826	Ext. Det.	--	Jaycor	B/W
2	I-805, PM NB 28.526	Ext. Det.	Ext. Det	--	Color
3	I-805, PM NB 18.296	Ext. Det	--	--	--
4	SR-163, PM NB 5.498	Ext. Det.	--	--	B/W
5	I-8, PM EB 39.300	Int. Det.	--	Davis	--
6	I-15, PM NB 12.957	Infrared	Infrared	--	--

GTE Test Sites.

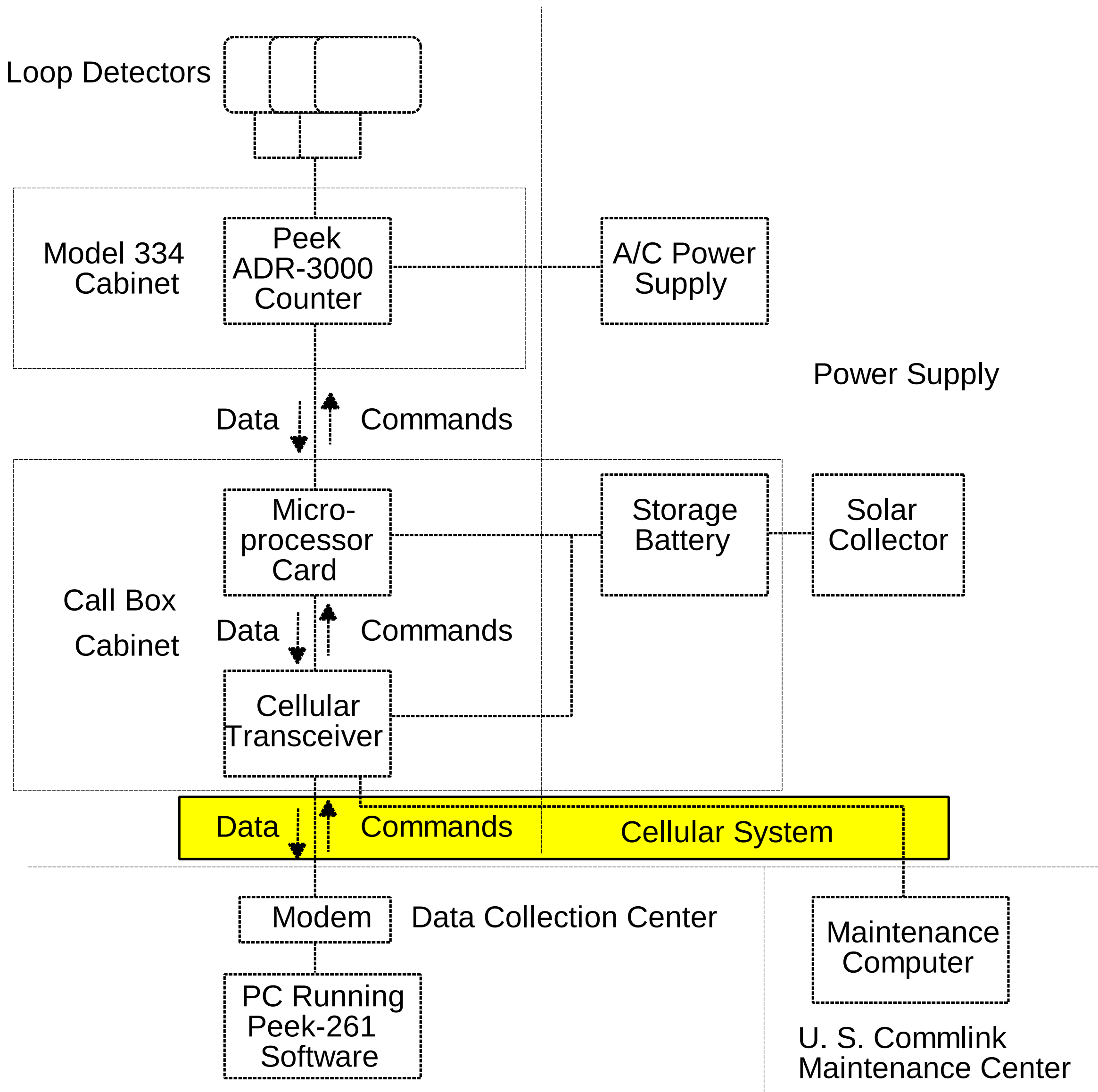
Site No.	Site	Subtest		
		Traf. Cen.	Incid. Det.	Weather
2,13	I-8, PM EB 0.214	Ext. Det.	Int. Det.	--
3,14	I-8, PM EB 1.450	Int. Det.	Int. Det.	--
4	I-5, PM SB 35.200	--	--	Jaycor
5	SR-75, PM NB 17.600	--	--	Jaycor
7	I-805, PM NB 17.380	--	Int. Det.	--
21	I-805, PM NB 25.300	--	Int. Det.	--
22	I-805, PM NB 26.430	--	Int. Det.	--
23	I-805, PM NB 20.888	--	Int. Det.	--

APPENDIX C

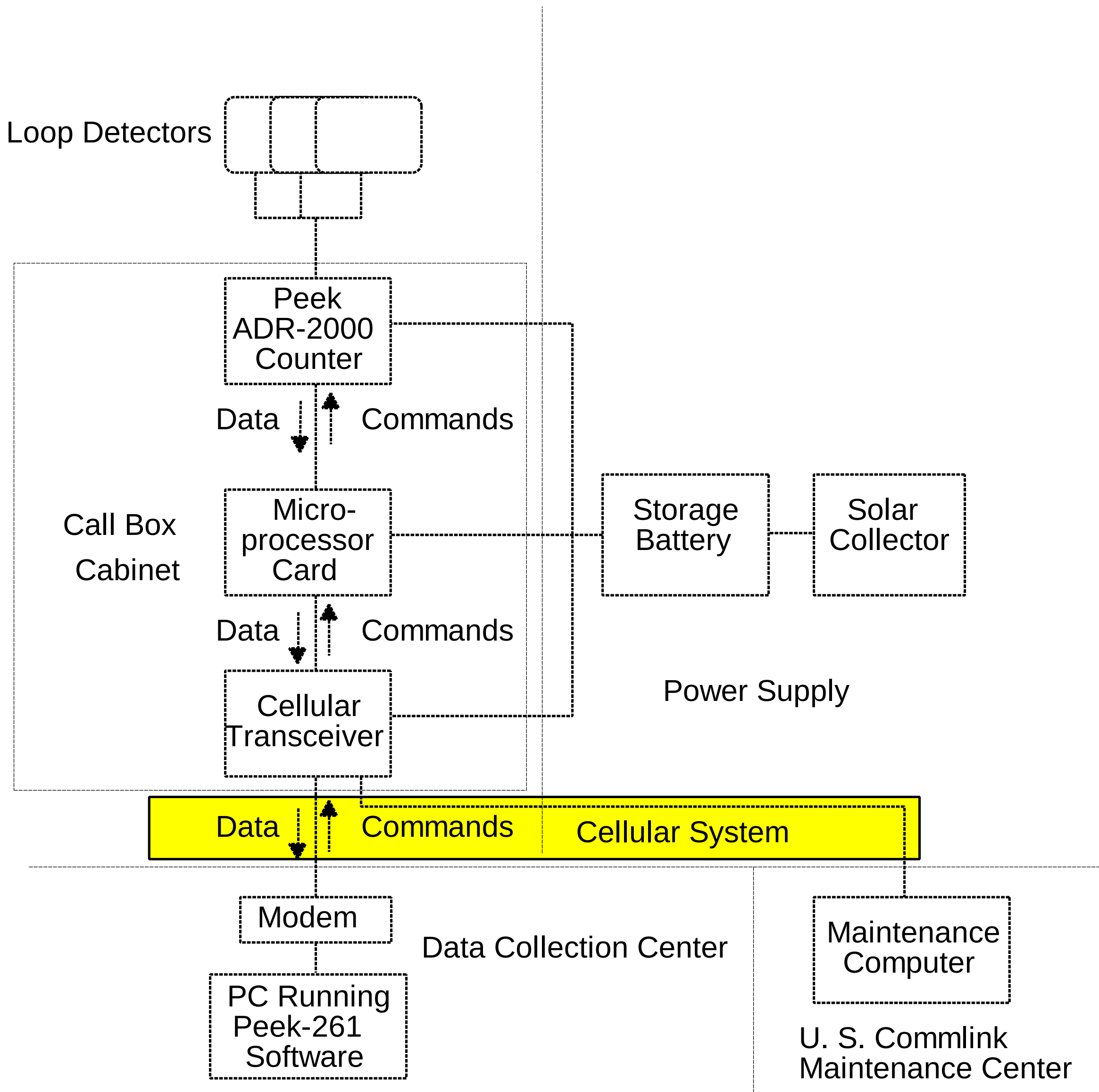
BLOCK DIAGRAMS OF TEST SYSTEMS

TRAFFIC CENSUS

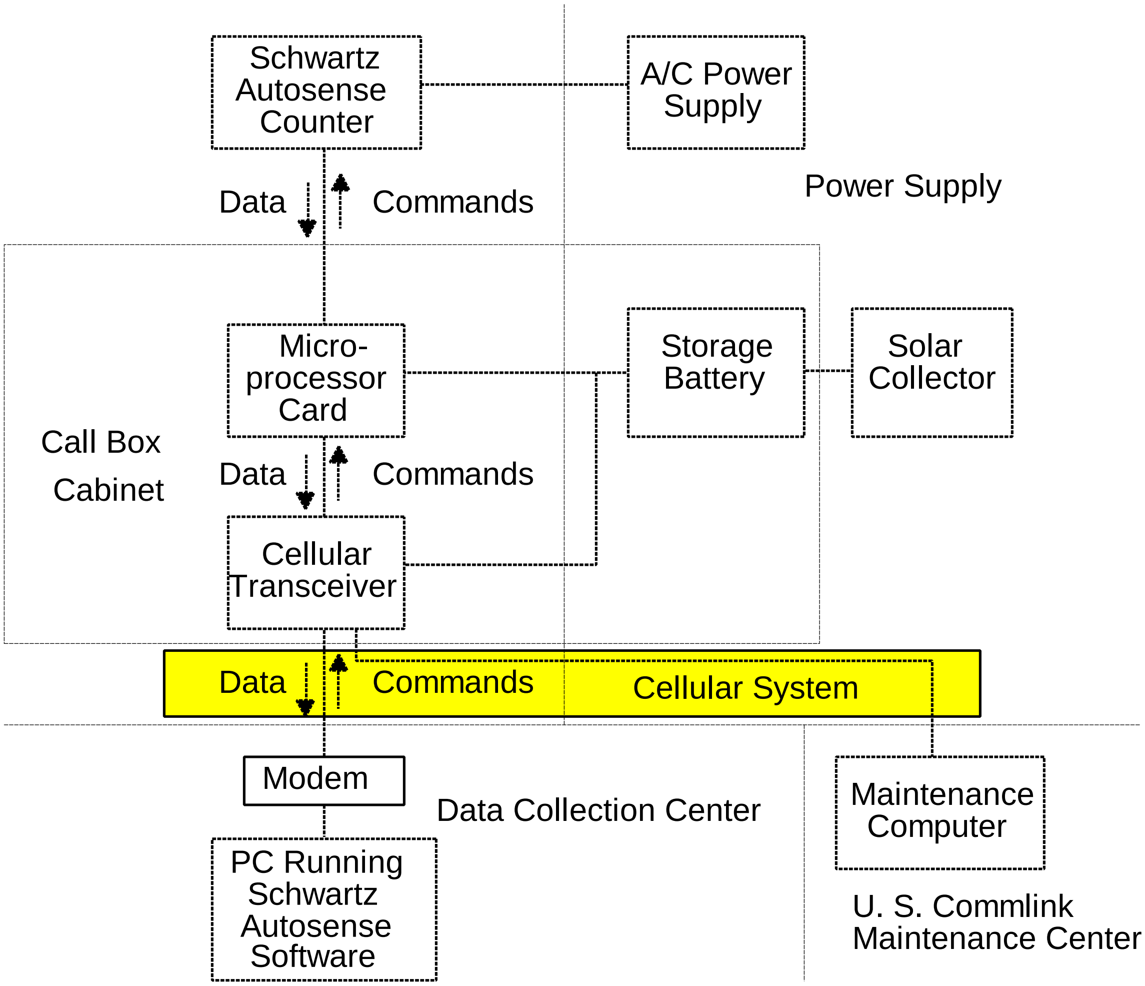
U. S. Commlink External Counter



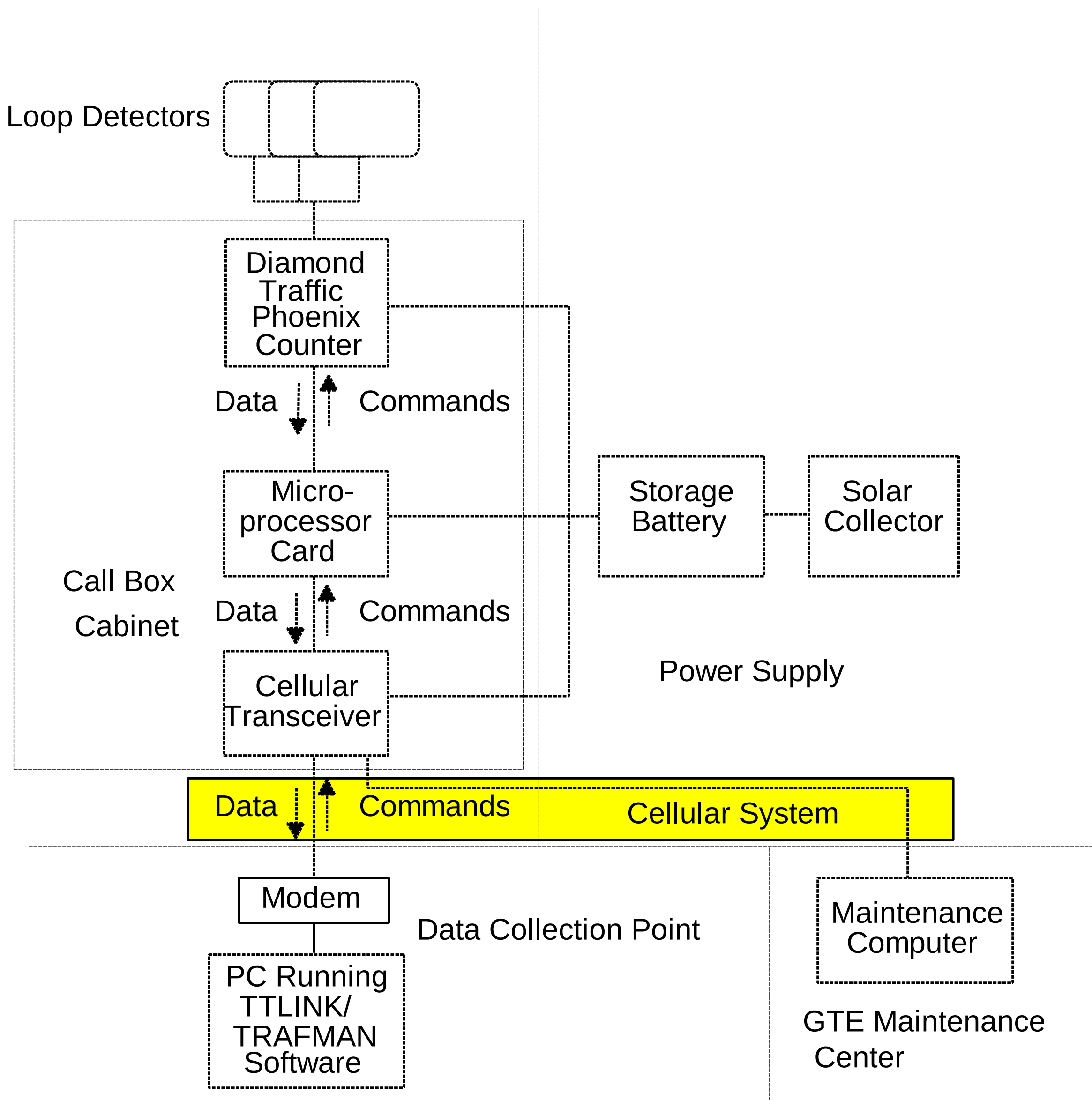
U. S. Commlink Internal Counter



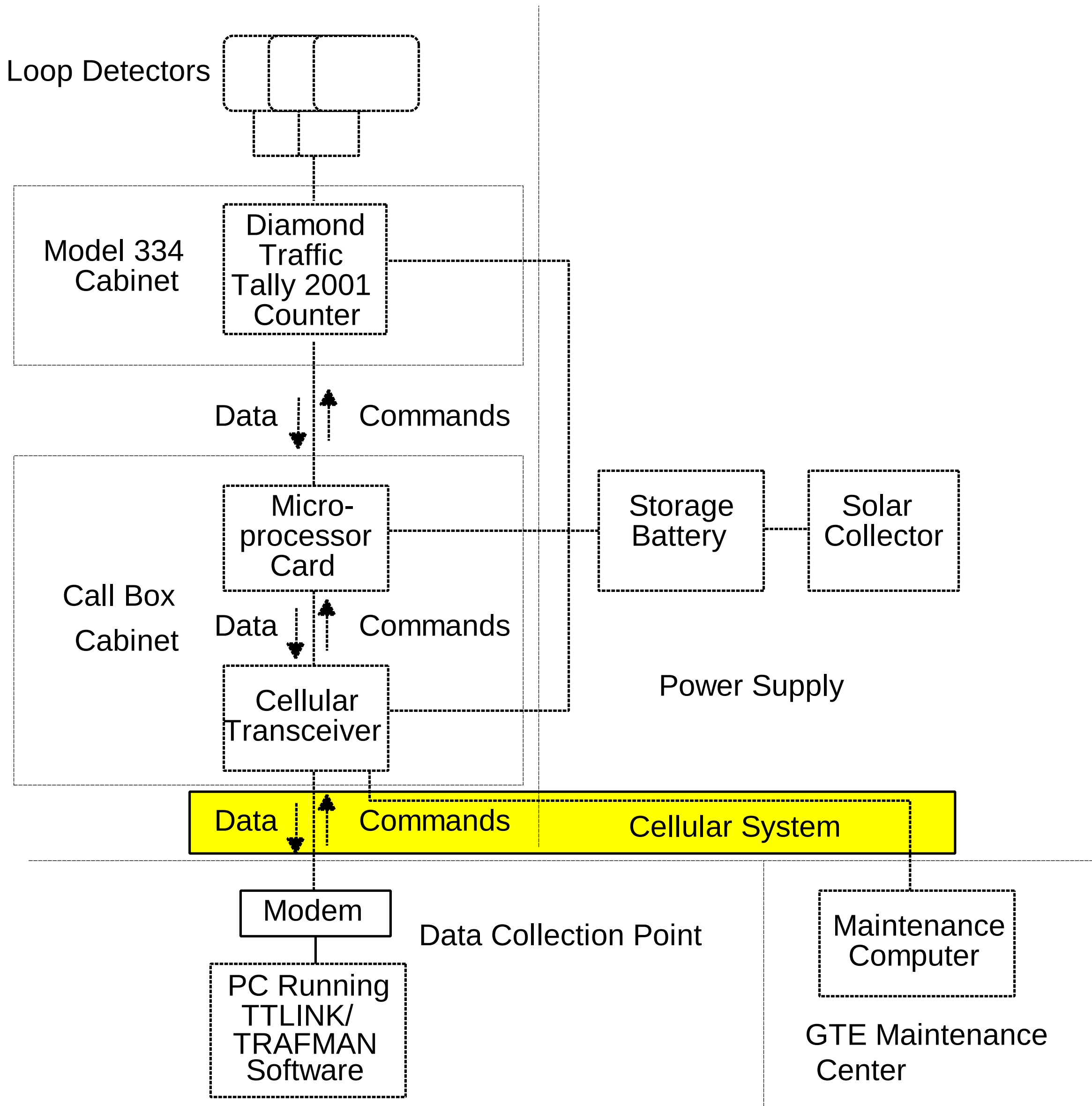
U. S. Commlink Infrared Counter



GTE Internal Counter

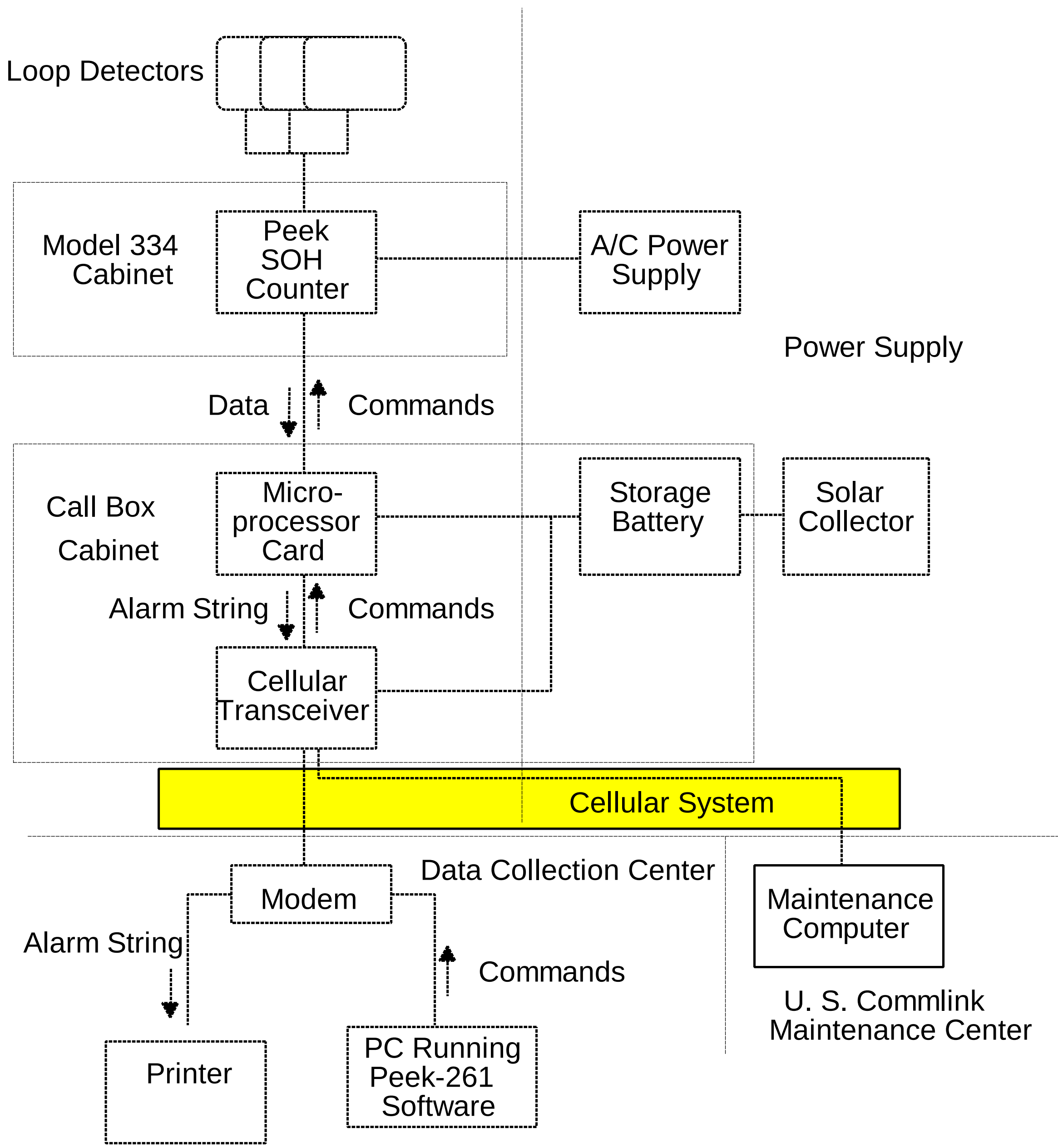


GTE External Counter

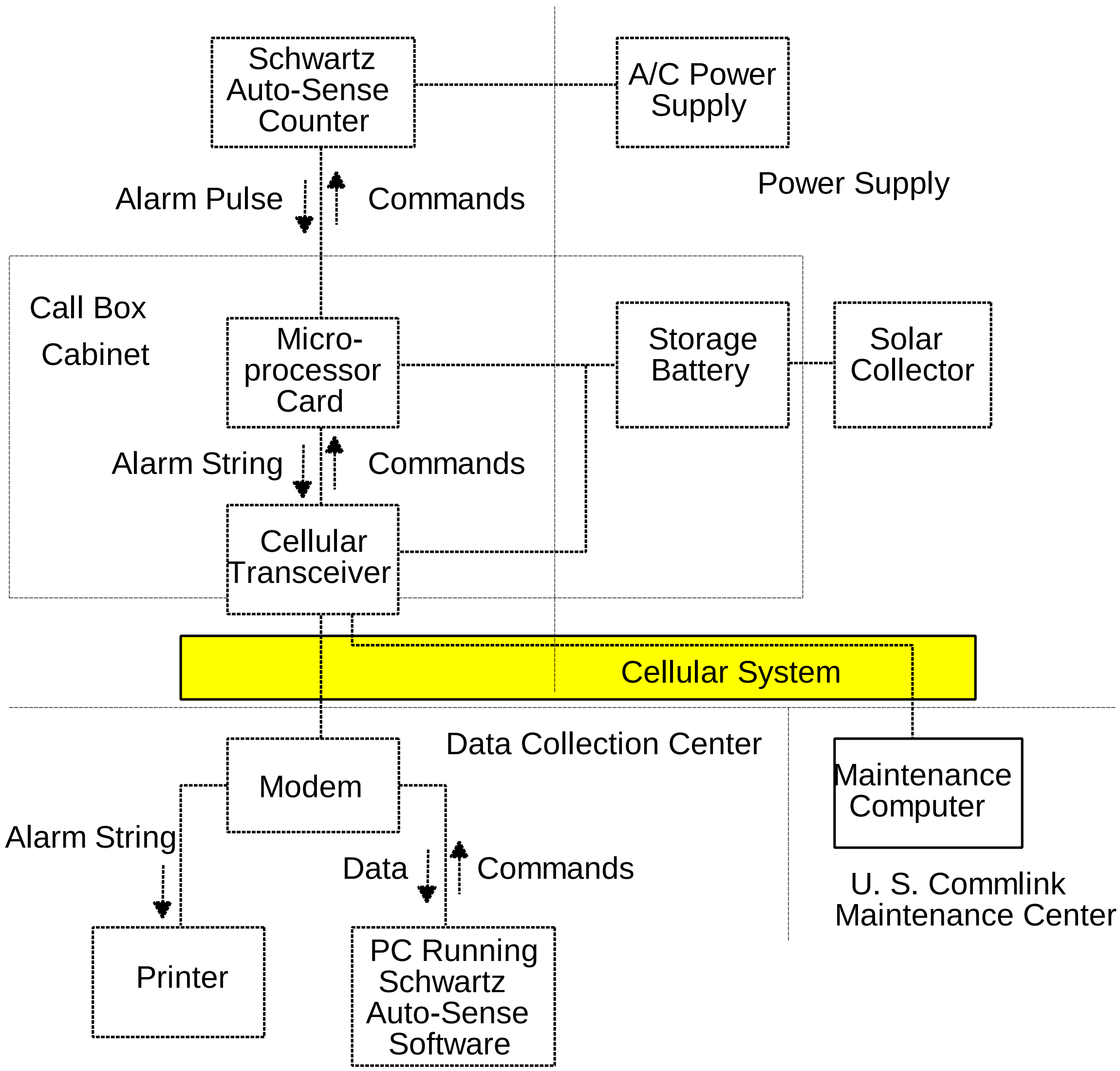


INCIDENT DETECTION

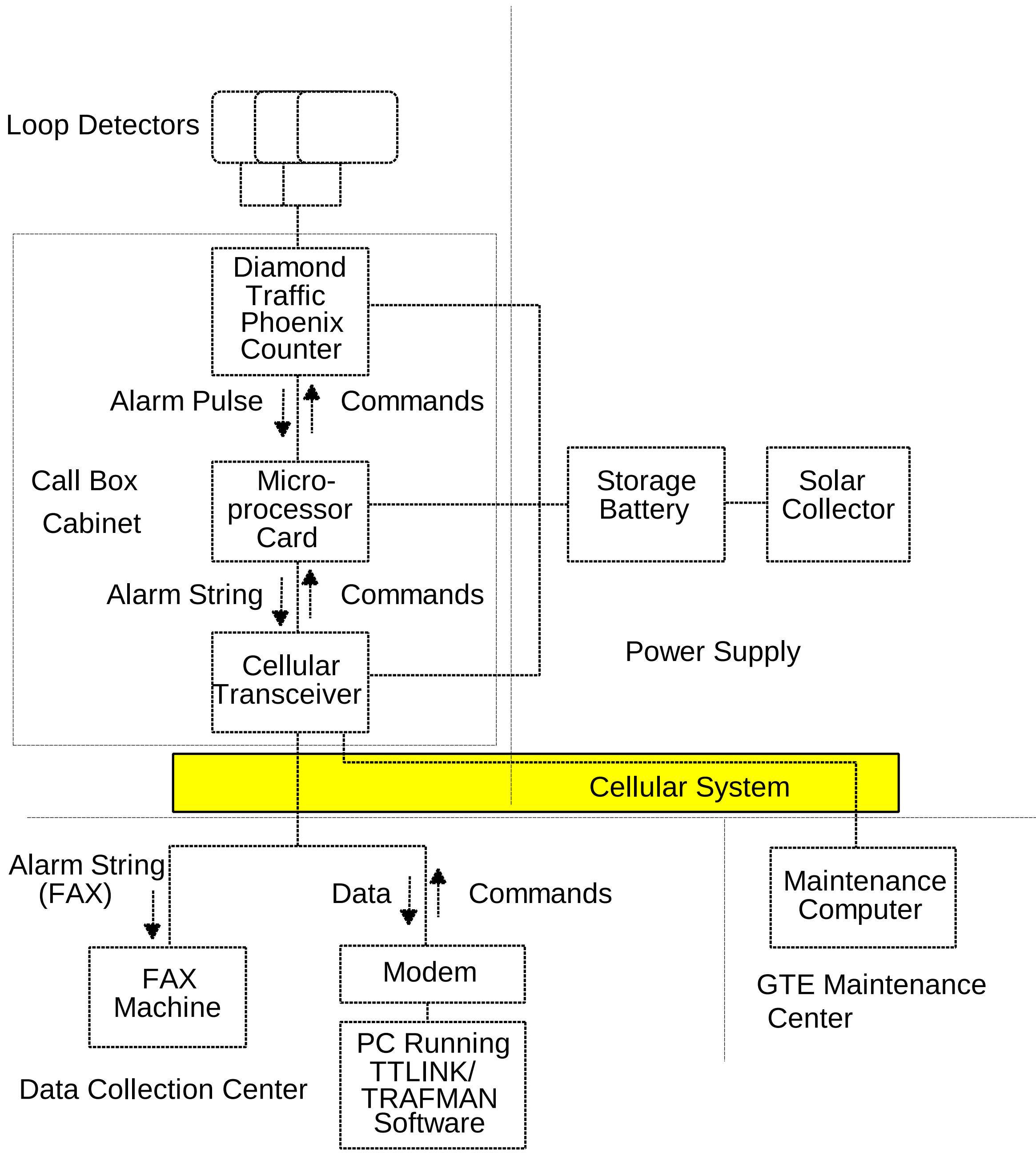
U. S. Commlink External Counter



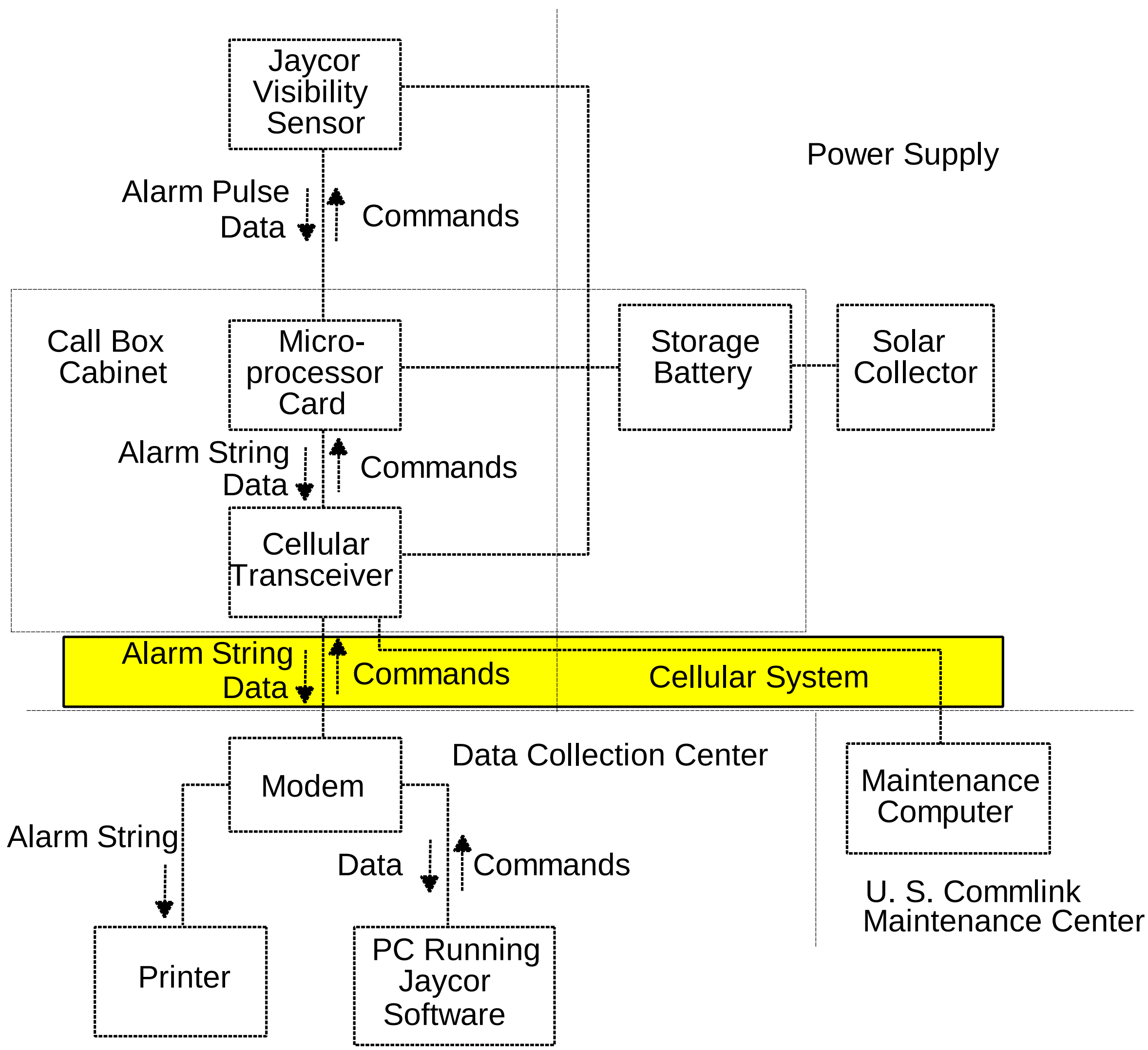
U. S. Commlink Infrared Counter



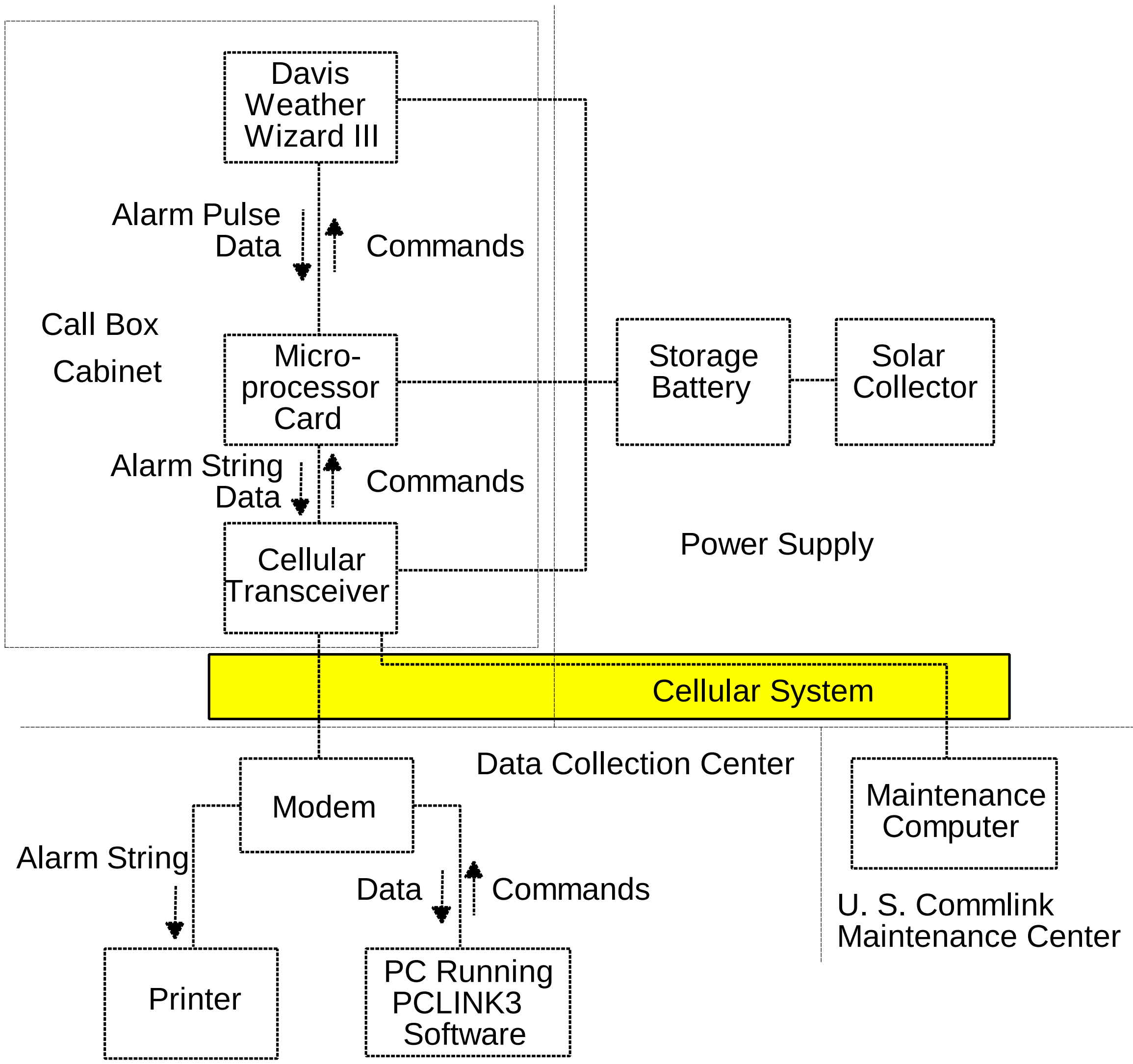
GTE Internal Counter



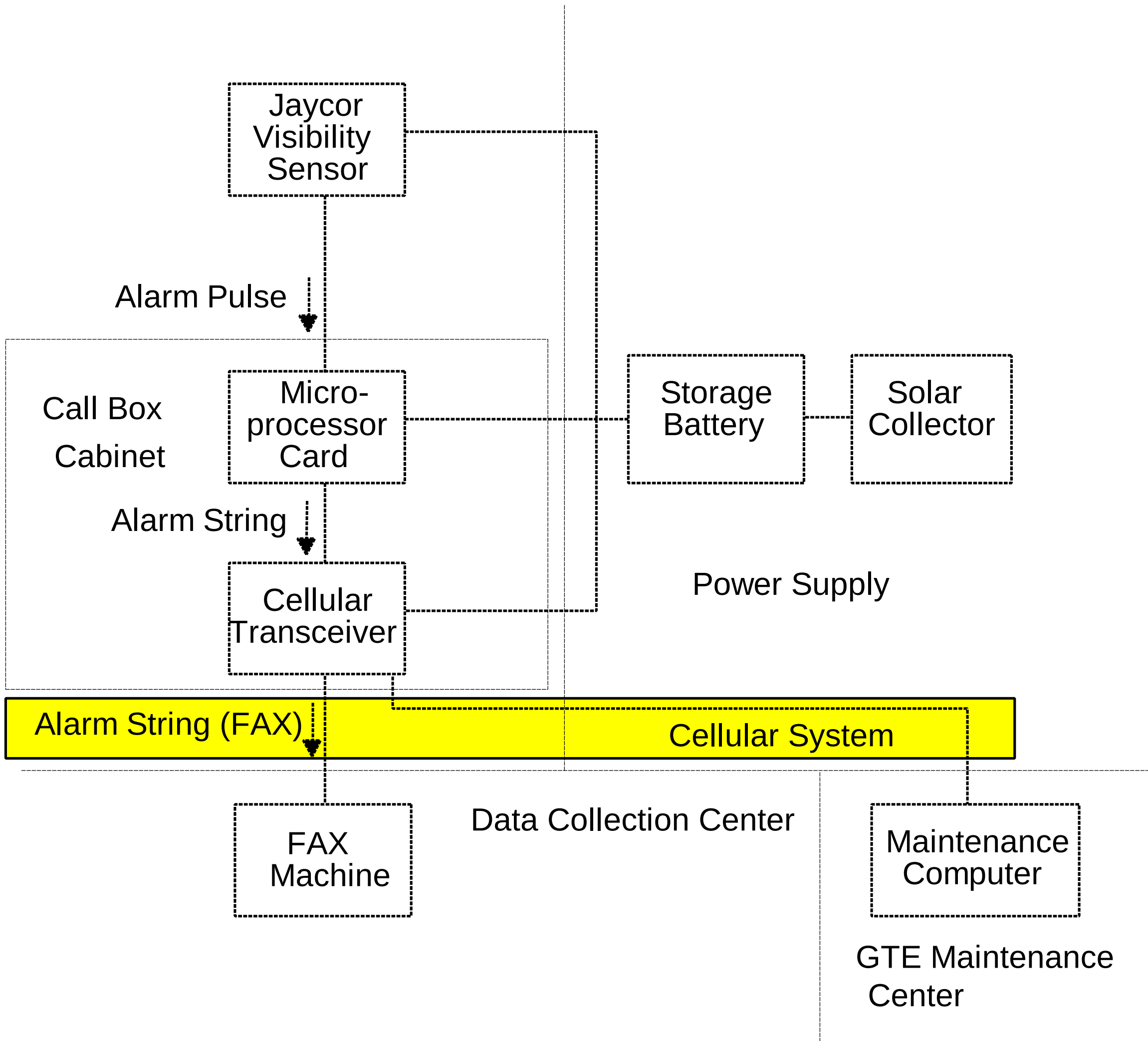
U. S. Commlink Visibility Sensor System



U. S. Commlink Davis Weather Station

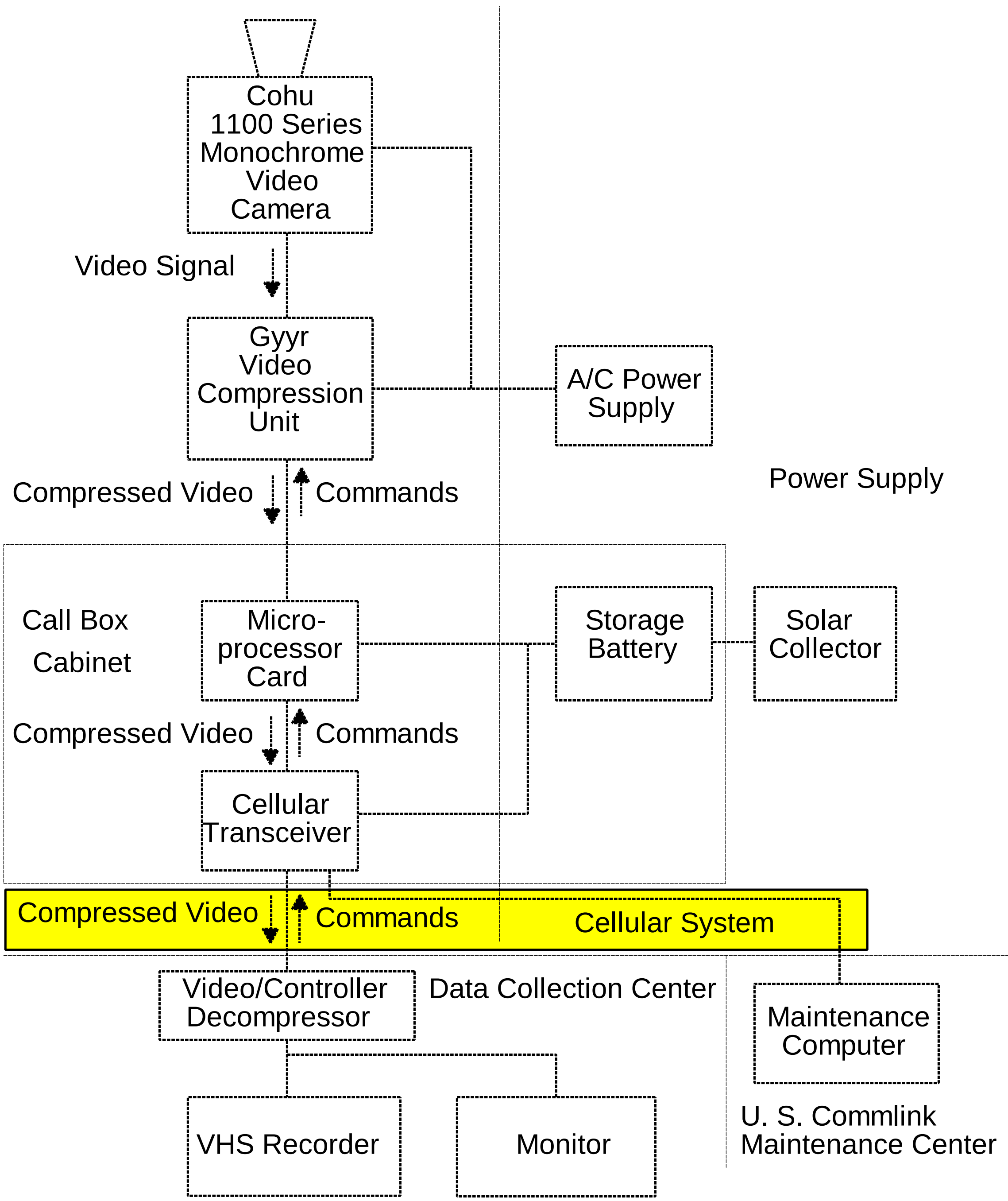


GTE Visibility Sensor System

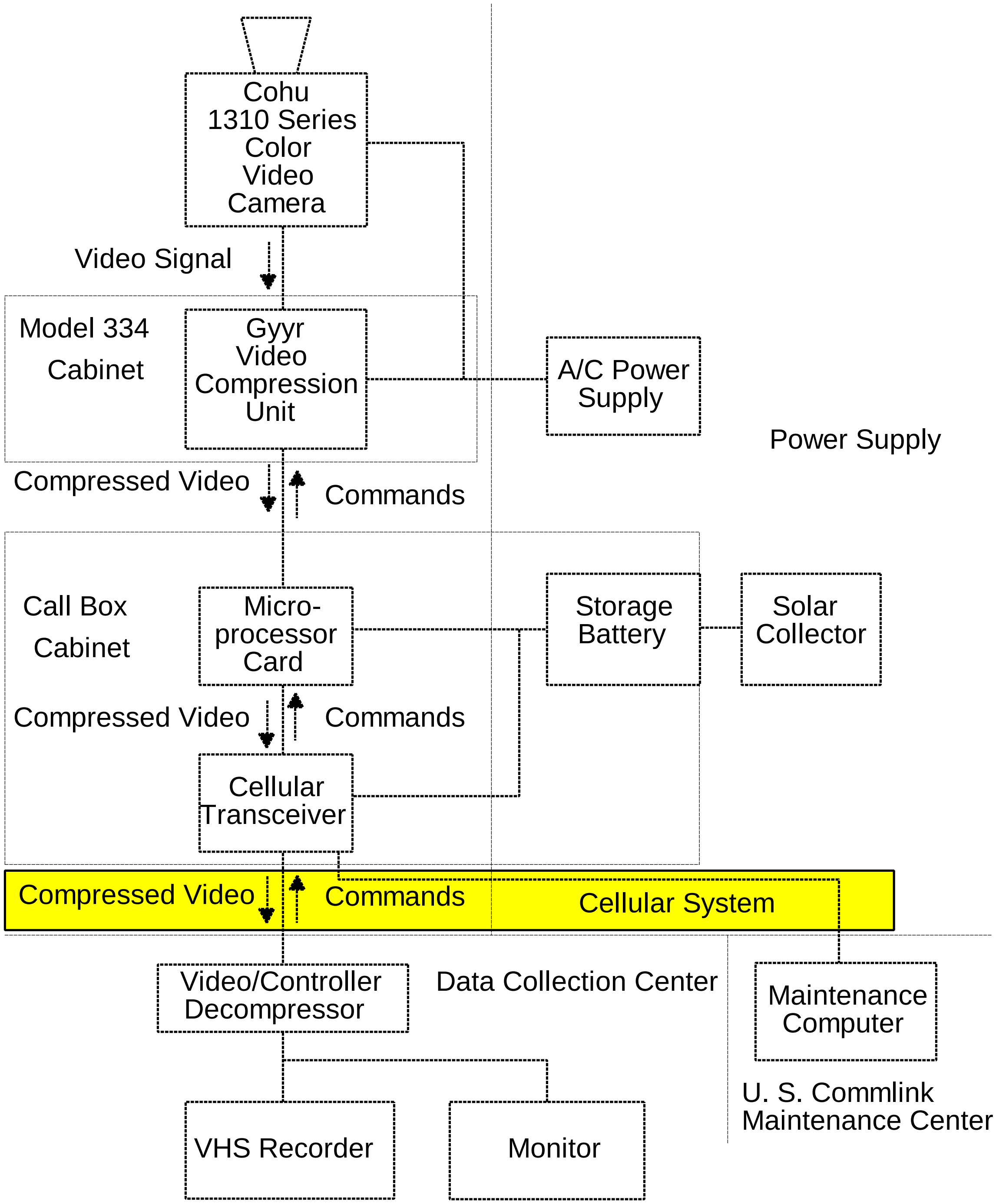


CCTV SURVEILLANCE SYSTEMS

U. S. Commlink Monochrome FFOV System



U. S. Commlink Color System



APPENDIX D

PERFORMANCE STANDARDS

TRAFFIC CENSUS SUBTEST

Counters: System must either interface with existing counters (Sarasota (now Peek) VT-1900) or must provide comparable capabilities. These include the following:

Count modes: Volume count, headway, axle classification, independent speed and length, correlated speed and length, statistical speed and length.

Memory: Must store up to 40 days worth of hourly counts from up to 12 detectors. Current counters have 25k characters (4-bit nibbles) with option to extent to 57k. Must have capability of resetting memory from data collection point.

Channels: At least 12 channels (detectors).

Time bases for counts: 1 minute, 2 minutes, 5 minutes, 6 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, 24 hours.

Transmission system:

Availability: Must provide 2 hour windows on four consecutive days (normally first and last days of month) during which transceiver is in receive mode. All data transmissions to be initiated from data collection point. Must have capability to reset time of day of window from the data collection point. For purposes of test, windows may need to be provided more frequently.

Data record description: 9 character ASCII records. (Note, if other than existing counters are used, 11 character records may be desirable.)

Maximum individual transmission: 6000 records.

Receive mode capabilities: Must be able to handle set up and interrogation commands. Commands for existing counters consist of up to 9 ASCII characters. Set up consists of up to 12 interactive steps. Existing counters provide for 18 interrogation commands and associated responses.

Remarks: It is desirable that counters, detectors, etc., be identical with existing in order to simplify job of Caltrans field crews. Use of equipment which results in increased training requirements is discouraged.

INCIDENT DETECTION SUBTEST

Algorithm: Algorithm must respond to threshold speeds of 50 MPH and 40 MPH. Speeds may be measured from double loops or from volumes and occupancies. Data smoothing routine to be identified later, but will probably be simple moving average over three to six minutes.

Required alarm conditions: Speed greater than 50 MPH; speed less than 50 MPH and greater than 40 MPH; speed less than 40 MPH.

Data to be transmitted: Single character alarm indicating first occurrence of particular threshold level, with location, date, and time stamp. Additional data may be specified later. In addition, system must be capable of transmitting standard system alarms and daily status information.

Data record description: 138-character ASCII string.

Data processing and transmission system: Proposed system must be capable of determining volumes, occupancies, and speeds from inductive loop detectors on a continuous basis, executing algorithm described above continuously, and transmitting alarms when appropriate.

Minimum system availability: 90%

Remarks: The "incident detection" system, as described by Caltrans District 11, is actually a congestion-detection system. No attempt will be made to implement an algorithm which can distinguish recurrent congestion from incident congestion. Also, no local calibration of the algorithm will be required. It is desirable if the system has the capability to add additional thresholds and to change threshold levels, however. Proposed system is intended to provide TMC operators a level of information similar to that from the existing ramp metering system, but on an alarm basis rather than a continuous basis.

HAZARDOUS WEATHER CONDITION DETECTION AND REPORTING SUBTEST

Algorithm: Algorithm must respond to weather indicator thresholds listed below.

Required alarm conditions: To be determined.

Data to be transmitted: Single character alarm indicating first occurrence of particular threshold level, with location, date, and time stamp. In addition, system must be capable of transmitting standard system alarms and daily status information.

Data record description: 138-character ASCII string.

Minimum system availability: 90%

Remarks: The Caltrans District does not require automatic weather alarms at present for operational purposes. The current system involves frequent updates of localized weather condition indicators, which are interpreted by maintenance personnel. The test is intended to develop a weather alarm system for use by the TMC; consequently, the test will involve determination and transmission of alarms.

CHANGEABLE MESSAGE SIGN CONTROL SUBTEST

Minimum allowable message length: 80-character ASCII stream for custom message transmissions from TMC to CMS.

Character sets to be supported: ASCII

Equipment compatibility requirements: Must be compatible with existing CMSs and PCs running "Signview" software.

Transmission confirmation requirements: Message displays must be validated by call box system. With current CMS technology, this means verifying switch condition rather than the actual display.

Data to be transmitted to TMC: Standard system alarms and daily status information. Also, message display validations.

Data record description: For transmissions from TMC to CMS, 80-character ASCII string; must be able to transmit 57-character custom sign display message strings and prompts for canned messages. For transmissions from call box to TMC, 138-character ASCII string.

Minimum system availability: 90%

Maximum per cent failed transmissions: 10%. Delayed transmissions will not be completed

Other: Message security is an issue. Dynamic encryption may be required. Also, must be able to activate from TMC at any time.

Remarks: At present, there is no intention by the Caltrans District to have canned messages automatically prompted by incident detection or weather reporting systems. All messages will be ordered from the TMC by human operators.

CCTV SURVEILLANCE SUBTEST

Field of vision and range: For incident verification, operational system must provide continuous coverage of the roadway, with all lanes and shoulders visible at all points. For CMS verification, must be focused on sign in question

Image quality requirements: For incident detection applications, color highly desirable; must be able to distinguish vehicle location and vehicles type (i. e., truck vs. car). For CMS verification, must be able to read CMS.

Digital data to be transmitted to TMC: Standard system alarms and daily status information.

Data record description: For CCTV to TMC, slow-scan video or better. For call box to TMC, 138-character ASCII string.

Minimum system availability: 90%

Maximum allowable per cent failed transmissions: 10%. Delayed transmissions will not be completed.

Minimum duration of sustained transmission: 5 minutes.

Other: Must be able to activate from TMC at any time.

APPENDIX E

COMPARISON OF TEST SYSTEM DESIGNS WITH PERFORMANCE STANDARDS AND SPECIFICATIONS

GTE Internal Counter Traffic Census Units

Specification or Standard	Status	Remarks
Count modes: volume, headway, axle classification, length, correlated speed and length, statistical speed and length	Yes	
Memory: Must store up to 40 days worth of hourly counts from up to 12 detectors. Current counters have 25k characters (4-bit nibbles) with option to extent to 57k. Must have capability of resetting memory from data collection point	Exceeded Yes	Standard memory option is 68 kB, expandable to 1 mB in 128 kB increments.
Channels: At least 12 channels (detectors).	Exceeded	16 channels
Time bases for counts: 1 minute, 2 minutes, 5 minutes, 6 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, 24 hours.	Yes	
Availability: Must provide 2 hour windows on four consecutive days (normally first and last days of month) during which transceiver is in receive mode. All data transmissions to be initiated from data collection point. Must have capability to reset time of day of window from the data collection point. For purposes of test, windows may need to be provided more frequently.	No	Actual maximum window is probably about 30 minutes. GTE Maintenance computer resets window unpredictably.
Data record description: 9 character ASCII records. (Note, if other than existing counters are used, 11 character records may be desirable.)	Yes	But native mode is binary.

GTE Internal Counter Traffic Census Units (Continued)

Specification or Standard	Status	Remarks
Maximum individual transmission: 6000 records	Yes	
Receive mode capabilities: Must be able to handle set up and interrogation commands. Commands for existing counters consist of up to 9 ASCII characters. Set up consists of up to 12 interactive steps. Existing counters provide for 18 interrogation commands and associated responses.	Yes	
It is desirable that counters, detectors, etc., be identical with existing in order to simplify job of Caltrans field crews. Use of equipment which results in increased training requirements is discouraged	Not this device	
Technologies which would eliminate or minimize the use of existing counters/controllers are highly desirable.	Yes	
Call boxes shall function as remote terminals to control the extraction of data stored in the traffic controllers.	Yes	
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other: Sensor status alarms	 Not in standards	 Omitted standard.

GTE External Counter Traffic Census Units

Specification or Standard	Status	Remarks
Count modes: volume, headway, axle classification, length, correlated speed and length, statistical speed and length	Yes	
Memory: Must store up to 40 days worth of hourly counts from up to 12 detectors. Current counters have 25k characters (4-bit nibbles) with option to extent to 57k. Must have capability of resetting memory from data collection point	Exceeded Yes	Standard memory option is 68 kB, expandable to 1 mB in increments of 128 kB.
Channels: At least 12 channels (detectors).	Exceeded	16 channels.
Time bases for counts: 1 minute, 2 minutes, 5 minutes, 6 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, 24 hours.	Yes	
Availability: Must provide 2 hour windows on four consecutive days (normally first and last days of month) during which transceiver is in receive mode. All data transmissions to be initiated from data collection point. Must have capability to reset time of day of window from the data collection point. For purposes of test, windows may need to be provided more frequently.	No	Actual maximum window is probably about 30 minutes. GTE Maintenance computer resets window unpredictably.
Data record description: 9 character ASCII records. (Note, if other than existing counters are used, 11 character records may be desirable.)	Yes	But native mode is binary.

GTE External Counter Traffic Census Units (Continued)

Specification or Standard	Status	Remarks
Maximum individual transmission: 6000 records	Yes	
Receive mode capabilities: Must be able to handle set up and interrogation commands. Commands for existing counters consist of up to 9 ASCII characters. Set up consists of up to 12 interactive steps. Existing counters provide for 18 interrogation commands and associated responses.	Yes	
It is desirable that counters, detectors, etc., be identical with existing in order to simplify job of Caltrans field crews. Use of equipment which results in increased training requirements is discouraged	Not this device	Need to verify maintenance requirements. If deployed, who would maintain?
Technologies which would eliminate or minimize the use of existing counters/controllers are highly desirable.	Not this device	
Call boxes shall function as remote terminals to control the extraction of data stored in the traffic controllers.	Yes	
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other: Sensor status reports	 Not in Standards	 Omitted standard

U. S. Commlink Infrared Detector Traffic Census Unit

Specification or Standard	Status	Remarks
Count modes: volume, headway, axle classification, length, correlated speed and length, statistical speed and length	Partially met	All except axle classification. Does do vehicle classification
Memory: Must store up to 40 days worth of hourly counts from up to 12 detectors. Current counters have 25k characters (4-bit nibbles) with option to extent to 57k. Must have capability of resetting memory from data collection point	No Yes	Currently designed with rotating 24-hour memory capability. But can be done only once per day at predetermined time.
Channels: At least 12 channels (detectors).	No	One per sensor; only one sensor installed. Can install up to 4 per call box.
Time bases for counts: 1 minute, 2 minutes, 5 minutes, 6 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, 24 hours.	No	Rotating 24-hr memory capability. Real-time screen displays can be set up for 10 sec, 30 sec, 1, 5, 10, 30, 60 minute averages
Availability: Must provide 2 hour windows on four consecutive days (normally first and last days of month) during which transceiver is in receive mode. All data transmissions to be initiated from data collection point. Must have capability to reset time of day of window from the data collection point. For purposes of test, windows may need to be provided more frequently.	Exceeded	Available for polling at any time.
Data record description: 9 character ASCII records. (Note, if other than existing counters are used, 11 character records may be desirable.)	No.	35-character records.

U. S. Commlink Infrared Detector Traffic Census Unit (Continued)

Specification or Standard	Status	Remarks
Maximum individual transmission: 6000 records	No	2048 records
Receive mode capabilities: Must be able to handle set up and interrogation commands. Commands for existing counters consist of up to 9 ASCII characters. Set up consists of up to 12 interactive steps. Existing counters provide for 18 interrogation commands and associated responses.	Yes	
It is desirable that counters, detectors, etc., be identical with existing in order to simplify job of Caltrans field crews. Use of equipment which results in increased training requirements is discouraged	No	
Technologies which would eliminate or minimize the use of existing counters/controllers are highly desirable.	Yes	
Call boxes shall function as remote terminals to control the extraction of data stored in the traffic controllers.	Yes	
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other: Support precise time interval standard	 Not in standards	 Omitted standard

U. S. Commlink Internal Counter Traffic Census Unit

Specification or Standard	Status	Remarks
Count modes: volume, headway, axle classification, length, correlated speed and length, statistical speed and length	Yes	Counter is VT-2000. Meets or exceeds all VT-1900 capabilities
Memory: Must store up to 40 days worth of hourly counts from up to 12 detectors. Current counters have 25k characters (4-bit nibbles) with option to extent to 57k. Must have capability of resetting memory from data collection point	Yes	
Channels: At least 12 channels (detectors).	Yes	
Time bases for counts: 1 minute, 2 minutes, 5 minutes, 6 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, 24 hours.	Yes	
Availability: Must provide 2 hour windows on four consecutive days (normally first and last days of month) during which transceiver is in receive mode. All data transmissions to be initiated from data collection point. Must have capability to reset time of day of window from the data collection point. For purposes of test, windows may need to be provided more frequently.	Exceeded	Able to be polled at any time
Data record description: 9 character ASCII records. (Note, if other than existing counters are used, 11 character records may be desirable.)	No	Ranges from 8 to 80 characters depending on type of data retrieved.

U. S. Commlink Internal Counter Traffic Census Unit (Continued)

Specification or Standard	Status	Remarks
Maximum individual transmission: 6000 records	Yes	
Receive mode capabilities: Must be able to handle set up and interrogation commands. Commands for existing counters consist of up to 9 ASCII characters. Set up consists of up to 12 interactive steps. Existing counters provide for 18 interrogation commands and associated responses.	Yes	
It is desirable that counters, detectors, etc., be identical with existing in order to simplify job of Caltrans field crews. Use of equipment which results in increased training requirements is discouraged	No	Newer model.
Technologies which would eliminate or minimize the use of existing counters/controllers are highly desirable.	Yes	
Call boxes shall function as remote terminals to control the extraction of data stored in the traffic controllers.	Yes	
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other: Sensor status report?	 Yes	 Omitted standard.

U. S. Commlink External Counter Traffic Census Units

Specification or Standard	**Status**	**Remarks**
Count modes: volume, headway, axle classification, length, correlated speed and length, statistical speed and length	Yes	Counter is VT-3000
Memory: Must store up to 40 days worth of hourly counts from up to 12 detectors. Current counters have 25k characters (4-bit nibbles) with option to extent to 57k. Must have capability of resetting memory from data collection point	Yes	
Channels: At least 12 channels (detectors).	Yes	
Time bases for counts: 1 minute, 2 minutes, 5 minutes, 6 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, 24 hours.	Yes	
Availability: Must provide 2 hour windows on four consecutive days (normally first and last days of month) during which transceiver is in receive mode. All data transmissions to be initiated from data collection point. Must have capability to reset time of day of window from the data collection point. For purposes of test, windows may need to be provided more frequently.	Exceeded	Able to poll at any time
Data record description: 9 character ASCII records. (Note, if other than existing counters are used, 11 character records may be desirable.)	No	Ranges from 8 to 80 characters depending on type of data retrieved.

U. S. Commlink External Counter Traffic Census Units (Continued)

Specification or Standard	Status	Remarks
Maximum individual transmission: 6000 records	Yes	
Receive mode capabilities: Must be able to handle set up and interrogation commands. Commands for existing counters consist of up to 9 ASCII characters. Set up consists of up to 12 interactive steps. Existing counters provide for 18 interrogation commands and associated responses.	Yes	
It is desirable that counters, detectors, etc., be identical with existing in order to simplify job of Caltrans field crews. Use of equipment which results in increased training requirements is discouraged	No	Newer model.
Technologies which would eliminate or minimize the use of existing counters/controllers are highly desirable.	N/A	
Call boxes shall function as remote terminals to control the extraction of data stored in the traffic controllers.	Yes	
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other: Sensor status report?	 Not in standards	 Omitted standard

GTE Internal Counter Incident Detection Units

Specification or Standard	Status	Remarks
Algorithm: Algorithm must respond to threshold speeds of 50 MPH and 40 MPH. Speeds may be measured from double loops or from volumes and occupancies.	Yes	Proper functioning of algorithm not verified.
Data smoothing routine: to be identified later, but will probably be simple moving average over three to six minutes.	Yes	Averages over 5 seconds. Detection on lane-by-lane basis.
Required alarm conditions: Speed greater than 50 MPH; speed less than 50 MPH and greater than 40 MPH; speed less than 40 MPH.	Yes	
Data to be transmitted: Single character alarm indicating first occurrence of particular threshold level, with location, date, and time stamp. Additional data may be specified later. In addition, system must be capable of transmitting standard system alarms and daily status information.	No	Transmits FAX. Message is actually "low visibility" because never updated from weather test. Does give location, date, and time
Data record description: 138-character ASCII string.	No	Is not transmitted to computer file.
Data processing and transmission system: Proposed system must be capable of determining volumes, occupancies, and speeds from inductive loop detectors on a continuous basis, executing algorithm described above continuously, and transmitting alarms when appropriate.	No	No confirmed alarms transmitted.

GTE Internal Counter Incident Detection Units (Continued)

The call boxes shall be capable of being remotely programmed to allow adjustments to the incident detection thresholds.	No	
Technologies which would eliminate or minimize the use of existing counters and/or controllers are highly desirable.	Yes	
Call boxes used to support incident detection will be linked to specific CMSs in Subtest 4.	N/A	Subtest 4 canceled.
Calls reporting threshold conditions shall be downloaded through the call boxes and over the cellular network on an as-occurring basis.	Failed	No confirmed alarms transmitted.
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	Actually reports 3-day summary.
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other:		

U. S. Commlink External Counter Incident Detection Units

Specification or Standard	**Status**	**Remarks**
Algorithm: Algorithm must respond to threshold speeds of 50 MPH and 40 MPH. Speeds may be measured from double loops or from volumes and occupancies.	Yes	Algorithm does not appear to be accurate.
Data smoothing routine: to be identified later, but will probably be simple moving average over three to six minutes.		Don't know details
Required alarm conditions: Speed greater than 50 MPH; speed less than 50 MPH and greater than 40 MPH; speed less than 40 MPH.	Yes	
Data to be transmitted: Single character alarm indicating first occurrence of particular threshold level, with location, date, and time stamp. Additional data may be specified later. In addition, system must be capable of transmitting standard system alarms and daily status information.	Yes	
Data record description: 138-character ASCII string.	N/A	Doesn't transmit string
Data processing and transmission system: Proposed system must be capable of determining volumes, occupancies, and speeds from inductive loop detectors on a continuous basis, executing algorithm described above continuously, and transmitting alarms when appropriate.	Yes	

U. S. Commlink External Counter Incident Detection Units (Continued)

The call boxes shall be capable of being remotely programmed to allow adjustments to the incident detection thresholds.	No	
Technologies which would eliminate or minimize the use of existing counters and/or controllers are highly desirable.	Yes	
Call boxes used to support incident detection will be linked to specific CMSs in Subtest 4.	N/A	Subtest 4 canceled
Calls reporting threshold conditions shall be downloaded through the call boxes and over the cellular network on an as-occurring basis.	Yes	
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other:	N/A	

U. S. Commlink Infrared Detector Incident Detection Unit

Specification or Standard	**Status**	**Remarks**
Algorithm: Algorithm must respond to threshold speeds of 50 MPH and 40 MPH. Speeds may be measured from double loops or from volumes and occupancies.	Yes	Algorithm does not appear to be accurate.
Data smoothing routine: to be identified later, but will probably be simple moving average over three to six minutes.	Unknown	
Required alarm conditions: Speed greater than 50 MPH; speed less than 50 MPH and greater than 40 MPH; speed less than 40 MPH.	Yes	
Data to be transmitted: Single character alarm indicating first occurrence of particular threshold level, with location, date, and time stamp. Additional data may be specified later. In addition, system must be capable of transmitting standard system alarms and daily status information.	Yes	
Data record description: 138-character ASCII string.	No	35 character records.
Data processing and transmission system: Proposed system must be capable of determining volumes, occupancies, and speeds from inductive loop detectors on a continuous basis, executing algorithm described above continuously, and transmitting alarms when appropriate.	N/A	Does not use loop detectors

U. S. Commlink Infrared Detector Incident Detection Unit (Continued)

The call boxes shall be capable of being remotely programmed to allow adjustments to the incident detection thresholds.	Yes	Schwartz can do this, but T-Cubed can't -- the software support is lacking.
Technologies which would eliminate or minimize the use of existing counters and/or controllers are highly desirable.	Yes	
Call boxes used to support incident detection will be linked to specific CMSs in Subtest 4.	N/A	Subtest 4 canceled
Calls reporting threshold conditions shall be downloaded through the call boxes and over the cellular network on an as-occurring basis.	Yes	
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other:	N/A	

GTE Visibility Units

Specification or Standard	**Status**	**Remarks**
Algorithm: Algorithm must respond to weather indicator thresholds listed below.	Yes	
Required alarm conditions: 300 feet visibility.	Yes	
Data to be transmitted: Single character alarm indicating first occurrence of particular threshold level, with location, date, and time stamp. In addition, system must be capable of transmitting standard system alarms and daily status information.	Changed by proposal Does not transmit all-clear	Sends FAX - gives device location, low visibility detected, date and time. Omitted standard. May also need visibility range during alarm conditions.
Data record description: 138-character ASCII string.	No	Is not transmitted to computer file.
Capable of being remotely programmed to allow adjustments in threshold parameters.	No	No connection between call box and sensor to allow reprogramming.
Call boxes used to support weather detection will be linked to specific CMSs on Subtest 4.	No	RFP requirement, withdrawn by Performance Standards per Caltrans request.

GTE Visibility Units (Continued)

Weather conditions of interest: temperature dew point fog wind velocity and direction icing	 No No Yes No No	 All but fog eliminated in proposal review stage. Sensor capable of giving visibility in feet and temperature, but no alarms reported for these.
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other: Ability to verify sensor status. Ability to query details of conditions reported by sensor.	 No No	 Omitted standard. Omitted standard. What may actually be needed is a network of sensors.

U. S. Commlink - Davis Weather Station Unit

Specification or Standard	Status	Remarks
Algorithm: Algorithm must respond to weather indicator thresholds listed below.	Yes	
Required alarm conditions: 20 mph wind speed.	Yes	Set to 20 MPH for test purposes only.
Data to be transmitted: Single character alarm indicating first occurrence of particular threshold level, with location, date, and time stamp. In addition, system must be capable of transmitting standard system alarms and daily status information.	Yes	Will provide date, location, and time. Format to be determined. Notification via FAX.
Data record description: 138-character ASCII string.	No	FAX
Capable of being remotely programmed to allow adjustments in threshold parameters.	No	Not as part of FOT
Call boxes used to support weather detection will be linked to specific CMSs on Subtest 4.	No	RFP requirement, withdrawn by Performance Standards per Caltrans request.

U. S. Commlink - Davis Weather Station Unit (Continued)

Weather conditions of interest: temperature dew point fog wind velocity and direction icing	 No No No Yes No	Sensor is also capable of dew point, humidity, barometric pressure, inside temperature, outside temperature, wind chill, and rain. No rain gauge hooked up to this unit. Can download data in all categories, but provides alarms only for wind.
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other: Sensor status reports?	 yes	 Omitted Standard.

Commlink - Jaycor Visibility Sensor Unit

Specification or Standard	**Status**	**Remarks**
Algorithm: Algorithm must respond to weather indicator thresholds listed below.	yes	
Required alarm conditions: 300 feet visibility.	yes	
Data to be transmitted: Single character alarm indicating first occurrence of particular threshold level, with location, date, and time stamp. In addition, system must be capable of transmitting standard system alarms and daily status information.	Yes Does not transmit all-clear	Notification via FAX. Omitted standard. May also need visibility range during alarm conditions. However, it can be queried for current conditions.
Data record description: 138-character ASCII string.	No	FAX
Capable of being remotely programmed to allow adjustments in threshold parameters.	No	Not as part of FOT
Call boxes used to support weather detection will be linked to specific CMSs on Subtest 4.	N/A	RFP requirement, withdrawn by Performance Standards per Caltrans request.

U. S. Commlink - Jaycor Visibility Sensor Unit (Continued)

Weather conditions of interest: temperature dew point fog wind velocity and direction icing	 No No Yes No No	Jaycor sensor capable of giving visibility in feet and temperature, but no alarms reported for these.
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other: Sensor status reports?	 yes	 Omitted Standard.

U. S. Commlink Monochrome FFOV CCTV Units

Specification or Standard	**Status**	**Remarks**
Field of vision and range: For incident verification, operational system must provide continuous coverage of the roadway, with all lanes and shoulders visible at all points. For CMS verification, must be focused on sign in question	Yes	
Image quality requirements: For incident detection applications, color highly desirable; must be able to distinguish vehicle location and vehicles type (i. e., truck vs. car). For CMS verification, must be able to read CMS.	Yes	
Data record description: For CCTV to TMC, slow-scan video or better. For call box to TMC, 138-character ASCII string.	Yes N/A	 No commands.
Minimum duration of sustained transmission: 5 minutes.	Exceeded	Up to 20 minutes.
Must be able to activate from TMC at any time. Time delays must be acceptable to TMC staff.	Yes Unknown	

U. S. Commlink Monochrome FFOV CCTV Units (Continued)

Experience indicates that pre-sets work well for PTZ installations	N/A	
Consider locating outside run-off zone.	N/A	
Sites to be coordinated with incident detection, CMS, and weather detection sites.	Yes	One site coordinated with visibility detection site; other site involves conventional CMS, and was proposed CMS test site prior to cancellation of CMS subtest.
Analysis of crash test results.	N/A	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other:	N/A	

U. S. Commlink Color FFOV CCTV Units

Specification or Standard	**Status**	**Remarks**
Field of vision and range: For incident verification, operational system must provide continuous coverage of the roadway, with all lanes and shoulders visible at all points. For CMS verification, must be focused on sign in question	Partly met	Installation is a single camera with a preset field of vision. Multiple installations required for continuous coverage.
Image quality requirements: For incident detection applications, color highly desirable; must be able to distinguish vehicle location and vehicles type (i. e., truck vs. car). For CMS verification, must be able to read CMS.	Yes	Unit does provide color.
Data record description: For CCTV to TMC, slow-scan video or better. For call box to TMC, 138-character ASCII string.	Yes N/A	 No commands. Unit is capable of being commanded, however.
Minimum duration of sustained transmission: 5 minutes.	Exceeded	Up to 20 minutes.
Must be able to activate from TMC at any time. Time delays must be acceptable to TMC staff.	Yes	

U. S. Commlink Color FFOV CCTV Units (Continued)

Experience indicates that pre-sets work well for PTZ installations	N/A	Single PTZ installation, local to site.
Consider locating outside run-off zone.	No	
Sites to be coordinated with incident detection, CMS, and weather detection sites.	Yes	Coordinated with incident detection subtest.
Analysis of crash test results.	No	May not be required per latest FHWA policy.
Produce daily call box status report.	Yes	
Transmit call box system alarms	Yes	
Must not interfere with normal call box operation.	Not tested	
Other:	N/A	

APPENDIX F

CAPITAL COST COMPARISONS

TRAFFIC CENSUS SITES

U. S. Commlink Site 1

Item	Test System	Baseline System
Call box and installation	$2,400	--
3,250’ Phone Cabling and trenching	--	35,750
Jaycor Visibility Sensor and Installation	2,500	2,500
30’ Tower and Foundation	1,000	1,000
CCTV (FFOV)	2,200	2,200
30’ Cabling and Trenching	330	330
334 Cabinet and Foundation	3,500	3,500
300’ Power Cable, Trenching, and Jacking	15,000	15,000
Peek ADR 3000 Counter	2,800	2,800
40’ CL5 Fencing and Installation	1,500	1,500
8 Induction Loops and Installation	6,800	6,800
(+$6,000 to run cables under traveled way)	6,000	6,000
5 Mile Markers and Installation	100	100
TOTAL	$44,130	$77,480

U. S. Commlink Site 2

Item	Test System	Baseline System
Call box and installation	$2,400	--
1,100’ Phone Cabling and Trenching	--	12,100
30’ Tower and Foundation	1,000	1,000
CCTV (PTZ)	6,600	6,600
334 Cabinet and Foundation	3,500	3,500
400’ Power Cable, Trenching, and Jacking	22,400	22,400
Peek ADR 3000 Counter	2,800	2,800
16 Induction Loops and Installation	12,000	12,000
(+$6,000 to run cables under traveled way)	6,000	6,000
100’ Cabling and Trenching	1,100	1,100
TOTAL	$57,800	$67,500

U. S. Commlink Site 3

Item	Test System	Baseline System
Call box and installation	$2,400	--
60’ Cabling and Installation	660	--
500’ Phone Cabling and Trenching	--	$5,500
334 Cabinet and Foundation	--	3,500
400’ Power Cable and Trenching	4,400	4,400
8 Induction Loops and Installation	6,800	6,800
(+$6,000 to run cables under traveled way)	6,000	6,000
Peek ADR 3000 Counter	2,800	2,800
TOTAL	$23,060	$29,000

U. S. Commlink Site 4

Item	Test System	Baseline System
Call box and installation	$2,400	--
300’ Phone Cabling and Trenching	--	$3,850
350’ Cabling and Installation	3,850	3,850
CCTV (FFOV)	1,500	1,500
8 Induction Loops and Installation	6,800	6,800
(+$6,000 to run cables under traveled way)	6,000	6,000
334 Cabinet and Foundation	3,500	3,500
Peek ADR 3000 Counter	2,800	2,800
TOTAL	$26,850	$28,300

U. S. Commlink Site 5

Item	Test System	Baseline System
Call box and Installation	$2,400	--
8,500’ Power Cable and Trenching	--	$93,500
8,500’ Phone Cable	--	8,500
334 Cabinet and Foundation	--	3,500
Davis Weather Sensors Assembly	195	195
Peek ADR 2000 Counter	3,300	3,300
2 Induction Loops and Installation	1,700	1,700
20’ Cabling and Trenching	220	220
TOTAL	$7,815	$110,915

U. S. Commlink Site 6

Item	Test System	Baseline System
Call box and Installation	$2,400	--
200’ Cabling, Conduit, and Trenching	2,200	--
7,100’ Phone Cable, Trenching, and Jacking	--	$83,500
100’ Cabling, Conduit, and Trenching	--	1,100
Schwartz Autosense	6,500	6,500
334 Cabinet and Foundation	3,500	3,500
3,820’ Power Cable, Trenching, and Jacking	58,220	58,220
Shoulder Closure	2,000	2,000
TOTAL	$75,920	$156,620

GTE Site 2

Item	Test System	Baseline System
Call box and Installation	$2,400	--
240’ Power Cable, Trenching, and Jacking	--	$10,740
240’ Phone Cable	--	240
334 Cabinet and Foundation	--	3,500
Diamond ?? Counter	1,100	1,100
6 Induction Loops and Installation	5,100	5,100
(+$2,000 to run cables under traveled way)	2,000	2,000
10’ Cabling and Trenching	110	110
TOTAL	$10,710	$22,790

GTE Site 3

Item	Test System	Baseline System
Call box and installation	$2,400	--
150’ Power Cable, Trenching, and Jacking	--	$6,150
115’ Phone Cable	--	115
334 Cabinet and Foundation	--	3,500
Diamond ?? Counter	1,100	1,100
30’ Cabling and Trenching	330	330
4 Induction Loops and Installation	3,400	3,400
TOTAL	$7,230	$14,595

INCIDENT DETECTION SITES

U. S. Commlink Site 2

Item	Test System	Baseline System
Call box and installation	$2,400	--
1,100’ Phone Cabling and Trenching	--	12,100
30’ Tower and Foundation	1,000	1,000
CCTV (PTZ)	6,600	6,600
334 Cabinet and Foundation	3,500	3,500
400’ Power Cable, Trenching, and Jacking	22,400	22,400
Peek SOH Counter	2,800	2,800
16 Induction Loops and Installation	13,600	13,600
(+$6,000 to run cables under traveled way)	6,000	6,000
100’ Cabling and Trenching	1,100	1,100
TOTAL	$59,400	$69,100

U. S. Commlink Site 6

Item	Test System	Baseline System
Call box and Installation	$2,400	--
200’ Cabling, Conduit, and Trenching	2,200	--
7,100’ Phone Cable, Trenching, and Jacking	--	$83,500
100’ Cabling, Conduit, and Trenching	--	1,100
Schwartz Autosense	6,500	6,500
334 Cabinet and Foundation	3,500	3,500
3,820’ Power Cable, Trenching, and Jacking	58,220	58,220
Shoulder Closure	2,000	2,000
TOTAL	$75,920	$156,620

GTE Site 7

Item	Test System	Baseline System
Call Box and Installation	$2,400	--
2,600’ Phone cable, trenching, and jacking	--	$38,500
350’ Power Cable and Trenching	--	3,850
334 Cabinet and Foundation	--	3,500
Diamond Counter/Processor	1,100	1,100
8 Induction Loops and Installation	6,800	6,800
10’ Trenching	100	100
TOTAL	$10,400	$51,150

GTE Site 13

Item	Test System	Baseline System
Call box and Installation	$2,400	--
240’ Power Cable, Trenching, and Jacking	--	$10,740
240’ Phone Cable	--	240
334 Cabinet and Foundation	--	3,500
Diamond ?? Counter	1,100	1,100
6 Induction Loops and Installation	5,100	5,100
(+$2,000 to run cables under traveled way)	2,000	2,000
10’ Cabling and Trenching	110	110
TOTAL	$10,710	$22,790

GTE Site 14

Item	Test System	Baseline System
Call box and installation	$2,400	--
150’ Power Cable, Trenching, and Jacking	--	$6,150
115’ Phone Cable	--	115
334 Cabinet and Foundation	--	3,500
Diamond ?? Counter	1,100	1,100
30’ Cabling and Trenching	330	330
4 Induction Loops and Installation	3,400	3,400
TOTAL	$7,230	$14,595

GTE Site 21

Item	Test System	Baseline System
Call box and installation	$2,400	--
5,500’ Power Cable, Trenching, and Jacking	--	$60,500
5,500’ Phone Cable	--	5,500
334 Cabinet and Foundation	--	3,500
Diamond Counter	1,100	1,100
8 Induction Loops and Installation	6,800	6,800
10’ Cabling and Trenching	110	110
TOTAL	$10,410	$77,510

GTE Site 22

Item	Test System	Baseline System
Call box and installation	$2,400	--
800’ Power Cable and Trenching	--	$8,800
830’ Phone Cable and jacking	--	3,830
334 Cabinet and Foundation	--	3,500
Diamond Counter/Processor	1,100	1,100
8 Induction Loops and Installation	6,800	6,800
10’ Cabling and Trenching	110	110
TOTAL	$10,410	$24,140

GTE Site 23

Item	Test System	Baseline System
Call box and installation	$2,400	--
4,000' Phone Cable and Trenching	--	$44,000
120' Power Cable and Trenching	--	1,320
334 Cabinet and Foundation	--	3,500
Diamond Counter/Processor	1,100	1,100
8 Induction Loops and Installation	6,800	6,800
10' Trenching	110	110
TOTAL	$10,410	$56,830

HAZARDOUS WEATHER DETECTION AND REPORTING SITES

U. S. Commlink Site 1

Item	Test System	Baseline System
Call box and installation	$2,400	--
3,250' Phone Cabling and trenching	--	35,750
Jaycor Visibility Sensor and Installation	2,500	2,500
30' Tower and Foundation	1,000	1,000
CCTV (FFOV)	2,200	2,200
30' Cabling and Trenching	330	330
334 Cabinet and Foundation	3,500	3,500
300' Power Cable, Trenching, and Jacking	15,000	15,000
Peek ADR 3000 Counter	2,800	2,800
40' CL5 Fencing and Installation	1,500	1,500
8 Induction Loops and Installation	6,800	6,800
(+$6,000 to run cables under traveled way)	6,000	6,000
5 Mile Markers and Installation	100	100
TOTAL	$44,130	$77,480

U. S. Commlink Site 5

Item	Test System	Baseline System
Call box and Installation	$2,400	--
8,500’ Power Cable and Trenching	--	$93,500
8,500’ Phone Cable	--	8,500
334 Cabinet and Foundation	--	3,500
Davis Weather Sensors Assembly	195	195
Peek ADR 2000 Counter	3,300	3,300
2 Induction Loops and Installation	1,700	1,700
20’ Cabling and Trenching	220	220
TOTAL	$7,815	$110,915

GTE Site 4

Item	Test System	Baseline System
Call box and installation	$2,400	--
5,900’ Power Cable, Trenching, and Jacking	--	$73,000
5900’ Phone Cable	--	5,900
334 Cabinet and Foundation	--	3,500
Jaycor visibility sensor and installation	2,500	2,500
TOTAL	$4,900	$84,900

GTE Site 5

Item	Test System	Baseline System
Call box and installation	$2,400	--
1,600’ Power Cable, Trenching, and Jacking	--	$24,800
1,600’ Phone Cable	--	1,600
334 Cabinet and Foundation	--	3,500
Jaycor visibility sensor and installation	2,500	2,500
TOTAL	$4,900	$32,400

CCTV SURVEILLANCE SITES

U. S. Commlink Site 1

Item	Test System	Baseline System
Call box and installation	$2,400	--
3,250’ Phone Cabling and trenching	--	35,750
Jaycor Visibility Sensor and Installation	2,500	2,500
30’ Tower and Foundation	1,000	1,000
CCTV (FFOV)	2,200	2,200
30’ Cabling and Trenching	330	330
334 Cabinet and Foundation	3,500	3,500
300’ Power Cable, Trenching, and Jacking	15,000	15,000
Peek ADR 3000 Counter	2,800	2,800
40’ CL5 Fencing and Installation	1,500	1,500
8 Induction Loops and Installation	6,800	6,800
(+$6,000 to run cables under traveled way)	6,000	6,000
5 Mile Markers and Installation	100	100
TOTAL	$44,130	$77,480

U. S. Commlink Site 2

Item	Test System	Baseline System
Call box and installation	$2,400	--
1,100’ Phone Cabling and Trenching	--	12,100
30’ Tower and Foundation	1,000	1,000
CCTV (PTZ)	6,600	6,600
334 Cabinet and Foundation	3,500	3,500
400’ Power Cable, Trenching, and Jacking	22,400	22,400
Peek ADR 3000 Counter	2,800	2,800
16 Induction Loops and Installation	12,000	12,000
(+$6,000 to run cables under traveled way)	6,000	6,000
100’ Cabling and Trenching	1,100	1,100
TOTAL	$57,800	$67,500

U. S. Commlink Site 4

Item	Test System	Baseline System
Call box and installation	$2,400	--
300' Phone Cabling and Trenching	--	$3,850
350' Cabling and Installation	3,850	3,850
CCTV (FFOV)	1,500	1,500
8 Induction Loops and Installation	6,800	6,800
(+$6,000 to run cables under traveled way)	6,000	6,000
334 Cabinet and Foundation	3,500	3,500
Peek ADR 3000 Counter	2,800	2,800
TOTAL	$26,850	$28,300

APPENDIX G

DOCUMENTS REVIEWED

Proposals and Work Plans

The Smart Call Box Proposed Field Operational Test, October, 1992.

Work Plan, Smart Call Box Field Operational Test, Preliminary (Rev. A), June 2, 1993.

Work Plan, Smart Call Box Field Operational Test, Preliminary (Rev. B), October 7, 1993.

Contracts and Agreements

Interagency Agreement, State of California - San Diego SAFE, March, 1994.

Contract, San Diego SAFE-Titan Corporation, March, 1994.

Subcontract, Titan Corporation-RMSL Traffic Systems, Inc., April, 1994.

Interagency Agreement, Caltrans-California PATH, September 27, 1994

Interagency Agreement, California PATH-SDSU Foundation, November 1, 1994.

Agreement, San Diego SAFE-U. S. Commlink, April 6, 1995.

Agreement, San Diego SAFE-GTE Telecommunications Services, Inc., June 26, 1995.

Evaluation Documents

Evaluation Plan, Version 1.0, November 21, 1994.

Individual Test Plans, Version 1.0, November 21, 1994.

Individual Test Plans, Version 1.1, February 8, 1995.

Individual Test Plans, Version 1.2, September 18, 1995.

Individual Test Plan, Institutional Issues, Version 1.0, November 21, 1994.

Individual Test Plan, Institutional Issues, Version 1.1, February 8, 1995

Data Management Plan, Version 1.0, January 17, 1995.

Evaluation Quality Control Procedures, Version 1.1, January 26, 1995.

SDSU Quarterly Progress Reports

January 19, 1995.

March 16, 1995.

June 15, 1995.

September 15, 1995.

RMSL/T-Cubed Monthly Progress Reports

March 29, 1994 - April 15, 1994.

April 16, 1994 - May 20, 1994.

May 23, 1994 - July 1, 1994.

July 2, 1994 - July 29, 1994.

July 30, 1994 - August 26, 1994.

August 27, 1994 - September 23, 1994.

September 24, 1994 - October 21, 1994.

December 31, 1994 - January 27, 1995.

January 28, 1995 - February 24, 1995.

February 25, 1995 - March 31, 1995

April 1, 1995 - April 28, 1995.

April 29, 1995 - May 26, 1995.

May 27, 1995 - June 30, 1995.

July 1, 1995 - July 28, 1995.

July 29, 1995 - August 25, 1995.

August 26, 1995 - September 22, 1995.

September 23, 1995 - October 27, 1995.

October 28, 1995 - December 1, 1995.

December 2, 1995 - December 29, 1995.

December 30, 1995 - January 26, 1996.

January 27, 1996 - March 1, 1996.

March 2, 1996 - March 29, 1996.

March 30, 1996 - April 26, 1996.

RMSL/T-Cubed Project Diaries

March 1, 1995 - May 10, 1995.

May 11, 1995 - July 3, 1995.

July 4, 1995 - May 29, 1996.

U. S. Commlink Project Diaries

June 24, 1994 - August 8, 1995.

August 9, 1995 - September 8, 1995.

September 9, 1995 - October 6, 1995.

October 7, 1995 - December 13, 1995.

December 14, 1995 - January 5, 1996.

January 6, 1996 - March 6, 1996.

March 7, 1996 - April 9, 1996.

April 10, 1996 - May 8, 1996.

GTE Project Summaries (Project Diaries)

July 1, 1995 - July 31,1995.

August 1, 1995 - August 31, 1995.

September 1, 1995 - September 31, 1995.

October 1, 1995 - October 31, 1995.

November 1, 1995 - November 30, 1995.

December 1, 1995 - December 31, 1995. (but actually received 12-14-95)

R. Sugita (Caltrans) Project Diaries

May 12, 1995 - August 8, 1995.

August 2, 1995 - September 29,1995

October 5, 1995 - November 1, 1995

November 2, 1995 - February 27, 1996.

February 29, 1996 - April 4, 1996.

RCT Quarterly Progress Reports

October 15, 1994.

January 15, 1995.

April 15, 1995.

July 15, 1995.

October 15, 1995.

January 15, 1996.

April 15, 1996.

Notes of Regional Coordination Team Meetings

March 2, 1994.

April 6, 1994.

June 1, 1994.

October 5, 1994.

November 2, 1994.

December 7, 1994.

January 11, 1995.

February 1, 1995.

March 1, 1995.

April 5, 1995.

May 3, 1995.

June 7, 1995.

August 2, 1995.

September 7, 1995.

October 5, 1995.

November 2, 1995.

December 7, 1995.

January 4, 1996.

January 30, 1996.

March 1, 1996.

April 5, 1996.

May 3, 1996.

Notes of Technical Advisory Team Meetings

February 8, 1995.

March 8, 1995.

May 10, 1995.

June 28, 1995.

August 9, 1995.

September 14, 1995

November 9, 1995.

December 14, 1995.

January 11, 1996.

March 7, 1996.

April 11, 1996.

May 9, 1996.

Notes of Other Meetings

SDSU-Caltrans (on Performance Standards), August 25, 1994

Banks-Triplett (on Performance Standards), October 3, 1994.

SDSU-RMSL-Caltrans, October 7, 1994.

SDSU-Caltrans-FHWA, October 31, 1994.

RCT-Vendor Negotiations, December 21, 1995.

Pre-TAC (RCT-U. S. Commlink), June 28, 1995.

FHWA-Booz-Allen & Hamilton-Caltrans-T-Cubed-SDSU, April 3, 1996.

Notes of Telephone Conversations

Banks-Tam, September 30, 1994.

Banks-Tam, January 11, 1994.

Lee-Banks, December 12,1995.

Letters and Memoranda

Dodd-Hardenburgh, July 7, 1994

Banks-Cechini, August 5, 1994.

Wells-Dodd, November 18, 1994.

Reed-Banks, February 9, 1995.

Dodd-RCT, February 15, 1995.

Dodd-Cechini, March 1, 1995.

Hardenburgh-Dodd, March 24, 1995.

Leyen-Dodd, April 3, 1995.

Dodd-Perkins, April 19, 1995.

Dodd-RCT, June 1, 1995.

FHWA Associate Administrators-Regional Administrators, July 27, 1995.

Churchill-RCT, August 9, 1995.

Banks-Tam, September 15, 1995.

Dodd-RCT, October 31, 1995.

Lee-Cather, September 25, 1995.

Banks-Tam, December 15, 1995.

USCL-RCT, January 26, 1996.

Dodd-RCT, February 6, 1996.

Dodd-Johnson, May 9, 1996.

Other Documents

Mitre Corporation, Guidelines for IVHS Operational Test Evaluation Plans, December 15, 1992.

Draft Request for Participation, July 27, 1994.

Revised Draft Request for Participation, August 8, 1994.

Claim of Exemption From Review, filed with SDSU Committee on Protection of Human Subjects, January 26, 1995.

Subphase 0 Diary, n. d. (Circa March 1, 1995).

RMSL Comments on GTE Contract Language Suggestions, April 19, 1995.

E-Mail Message, Joe Palen, distributed at TAC Meeting, August 9, 1995.

T-Cubed "White Paper" on CMS Test, February 29,1996.

Early Results Report, Subphase One, Draft, January 31,1996.

Exit Strategy Plan of Action and Milestones, March 1, 1996.

Exit Strategy Plan of Action and Milestones, April 1, 1996.

Exit Strategy Plan of Action and Milestones, May 3, 1996.

APPENDIX H

INSTITUTIONAL ISSUES INTERVIEW FORM

Smart Call Box Field Operational Test

Institutional Issues Interview Form

DATE ___________________

NAME ________________________________ PHONE NUMBER _______________

ORGANIZATION ____

Interviewer: The purpose of this interview is to document your perceptions about institutional issues encountered in the Smart Call Box field operational test. As you are aware, the purpose of the test was not just to demonstrate the technical feasibility of using smart call box technology to process and transmit traffic data, but also to determine what will be required to actually implement such a system. The questions I'm about to ask you will help us, as the Evaluators, to assess what institutional concerns will need to be resolved if such systems are to be widely implemented.

QUESTIONS:

1. What, in your opinion, were the major strengths and weaknesses in the way the field test itself was administered?

2. Do you believe that any of the institutional arrangements for the test had an effect on the design or technical performance of any of the test systems or that they otherwise affected the outcome of the test?

3. In your opinion, are there any institutional issues or problems that may have an impact on the implementation of a full-scale smart call box system?

4. Do you have any suggestions for how any of the issues you have identified can be avoided or overcome?

5. Do you have any other comments or suggestions?

APPENDIX I

INTERVIEW SUBJECTS

Organization	Individual	Type of Interview
Caltrans District 11	Richard Sugita	Personal
	Ross Cather	Personal
San Diego SAFE	Mike Perkins	Personal
	Patricia Honeycutt	Personal
CHP	Ken Ahacic	Telephone
RMSL Traffic Systems	Jim Dodd	Personal
	Jack Valenty	Personal
	Bruce Churchill	Personal
FHWA	Frank Cechini	Telephone
	Jackie Landsman	Telephone
California PATH	Robert Tam	Telephone
Caltrans Office of New Technology	Andrew Lee	Telephone
	Joe Palen	Telephone

INTERVIEW SUBJECTS (CONTINUED)

Organization	Individual	Type of Interview
Vendors:		
GTE	Stephen Van Wagoner	Telephone
	Phil Hombledal	Telephone
U. S. Commlink	Tom Leyen	Telephone
	Steve Ornellas	Telephone
Jaycor	Ray Denson	Telephone
Icon Networks	Brad Sousa	Telephone
Gyyr, Inc.	Steve Kuntz	Telephone
Cohu, Inc.	Curt Duplack	Telephone
Vaisala, Inc.	Leon Schneider	Telephone
Davis Instruments	Jim Aquistapace	Telephone
Swartz Electro-Optics	Terry Meyers	Telephone
Peek Traffic Systems	Ian Cardozo	Telephone

APPENDIX J

INSTITUTIONAL ISSUES LIST

ISSUES ENCOUNTERED IN THE CONDUCT OF THE FOT

1. Organizational structure
   a. Basic concept
   b. Lines of authority and responsibility
      1) Federal-State-local
      2) Evaluator-partners
      3) Project Manager-partners
      4) RCT-Project Manager-vendors
      5) Vendor teams
      6) FHWA consultants
   c. Reporting and communication
      1) Project Manager-RCT-State-FHWA
      2) Evaluator-PATH-State-FHWA
      3) Roles of RCT and TAC
      4) Communications within individual agencies
      5) Communication among prime vendors
      6) Communication within vendor teams
      7) Data access policies
      8) Public information policies
   d. Staffing

1) Stability of agency staffing

2) Stability of vendor staffing

e. Stability of private-sector corporate structures

2. Project scope

a. Geographical scope

b. Potential involvement of additional partners

3. Procurement policies and procedures

a. Procedures of agencies funding the FOT

1) Structure and sequencing of contracts

2) Complexity of contract approval processes

3) Financial arrangements

b. FOT procurement

1) Ownership of property

a) Physical property

b) Intellectual property

2) Procurement without payment or contract

3) RFP-proposal-negotiation process with vendors

4) Contracting processes

a) SAFE-RCT contracting relationship

b) Adaptation of standard County contracts

5) Financial arrangements

6) Specific provisions of vendor contracts

a) Liquidated damages

b) Approval of vendor's personnel changes

c) Delegation of technical control to RCT

d) Termination clause

e) Payment schedules

f) Procedures for approving changes to field tests

7) Contracts with cellular carriers

4. Permits and other official review and approval processes

   a. Encroachment permits

      1) Application process

      2) Enforcement of permit conditions

   b. Human subjects research reviews and approvals

5. Conduct of FOT

   a. Vendor motivation

   b. Enforcement of contract provisions

   c. Project management decisions

6. Community esthetic concerns

ADDITIONAL ISSUES RELATED TO DEPLOYMENT OF SMART CALL BOX SYSTEMS

1. Basic procurement models

   a. California

   b. Outside California

2. Ownership of smart call box systems

a. California

b. Outside California

3. Financial arrangements

a. Funding sources

b. Interagency compensation arrangements

4. Market size and profitability

5. Deployment contracts

a. Exclusive-vendor clauses

b. Risk assignment

1) Theft

2) Damaged equipment

6. Maintenance arrangements

7. Environmental documentation

8. Incorporation of data into existing databases

APPENDIX K

INSTITUTIONAL ISSUES ANALYSIS SUMMARIES

ISSUES RELATED TO DEPLOYMENT

Issue: ***Compatibility of System Designs with Transportation System Management Needs***

Description: Do the system designs developed by the Smart Call Box FOT meet the needs of potential users? Whose input should have been sought, and at what stage in the FOT?

Raised by: Evaluator, Caltrans Office of New Technology and Research, Caltrans District 11, FHWA, PATH, Vendors

Seriousness: Potentially crucial to deployment.

Discussion: This issue is 1) whose specifications are adopted the development of test system designs and 2) how does this affect acceptance of the systems by potential users. In the case of the Smart Call Box FOT, the test systems were intended to be used by transportation system management personnel nationwide. Four groups participated to some extent in the development of test system standards and specifications: 1) local Caltrans operations personnel who were potential users of the systems; 2) the project management team consisting of the RCT, the Project Manager, and the Evaluator; 3) the vendors; and 4) the sponsoring agencies, such as FHWA and the Caltrans Office of New Technology and Research.

Each of these groups had a somewhat different perspective. Local Caltrans operations personnel were concerned that test systems serve very specific needs that they already recognized; consequently, this group tended to favor conservative designs which might not be geographically transferable. The project management team was more concerned with developing a wide range of call-box-based technology, but was still looking for systems that could be implemented locally. The vendors were presumably interested in developing systems that could be marketed on a nationwide basis, but were also needed to produce workable systems within the time and resource constraints of the FOT. The sponsoring agencies were concerned with “interesting” technical applications and geographical transferability of the results.

Effective control of the FOT lay with the Project Manager and the RCT. Both the FOT proposal and the RFP were written by the Project Manager with the approval of the FOT partners (in the case of the proposal) or the RCT (in the case of the RFP). Local Caltrans operations personnel had input into the FOT through formal performance standards, which were developed by the Evaluator in consultation with them and adopted by the RCT, and through participation in the TAC. The performance standards, however, were issued relatively late in the process, about a week before the initial proposals were due from the vendors. The vendors provided the detailed system designs under the direct supervision of the Project Manager, and also participated in negotiations with the RCT and the Project Manager that helped define the FOT's scope and the underlying system concepts.

A number of participants raised questions about the effectiveness of the communication between the RCT and the vendors. In some cases, concern was expressed that the RCT's technical expectations were unclear, not detailed enough, and unstable over time; on the other hand, other participants felt they were too rigid or that vague expectations were appropriate, given the nature of the test.

The sponsoring agencies had little input to system specifications: one individual in the Caltrans Office of New Technology and Research did offer suggestions, but these were not provided in a timely fashion . Otherwise, the only mechanism available for input from the sponsoring agencies was the review of the Evaluation Plans and the Individual Test Plans for the subtests. Also, there was no formal mechanism for incorporating input from operations personnel outside the San Diego area, although the Project Manager and the Caltrans representatives to the RCT did have contacts elsewhere in California who may have influenced specifications to some extent.

Ways to Avoid or Mitigate Potential Problems: This problem might have been avoided by careful consideration of ways to solicit input about system designs at an early stage in the FOT. Ideally, a series of discussions involving the RCT, the Project Manager, representatives of the sponsoring agencies, potential vendors, and potential users from various geographical areas would have been held prior to issuance of the RFP. The goal of these discussions would have been to identify the scope of the test and to clarify issues related to 1) the feasibility of proposed system features or 2) their compatibility with TMC operations in different geographical settings.

Actions Required for Resolution: None as far as this FOT is concerned (it's too late now). Future projects involving development of intelligent transportation system components should incorporate early discussions of system specifications and requirements. Such discussions should involve a full range of interested parties to ensure the acceptance and geographical transferability of the results.

Issue: ***Basic Procurement Concepts for Deployment***

Description: Should smart call box systems be installed and maintained by public sector agencies or private sector vendors?

Raised by: Evaluator, Project Manager, RCT, Caltrans District 11, Vendors

Seriousness: Potentially crucial to deployment; different choices as to basic procurement model lead to different sets of institutional issues.

Discussion: Emergency call box systems in California are managed by a private-sector consultant and installed and maintained by vendors. The most likely scenario for deployment of smart call boxes in California is some sort of minor modification of this system, although other models have been proposed and may be attempted. Elsewhere, other procurement models may be favored. Many state transportation departments may favor a model in which they manage smart call box systems directly, and in which maintenance and possibly even installation are performed by their own employees. These two procurement models will be referred to as the "private-sector" model and the "public-sector" model. Various combinations of these two models are also possible. Different institutional issues and problems may be encountered, depending on which model is chosen. These are analyzed separately.

Major advantages of the private-sector model include the following:

- Requires minimal public staffing
- May result in more expert and efficient management, if the management consulting firm specializes in this type of work and can cover several geographical areas
- May result in more expert maintenance, since the vendors should be thoroughly familiar with their own products
- May provide an incentive for vendors to supply reliable equipment if they are also responsible for maintenance
- May allow for more flexibility in funding arrangements

Advantages of the public sector model include the following:

- Provides the public agency with direct control of the day-to-day management of the system
- Avoids need for outside contracts and the delays, expense, and inconvenience associated with processing them
- Avoids the need to pay for overhead on private sector contracts

Ways to Avoid or Mitigate Potential Problems: Before decisions about basic procurement models for deployment of smart call boxes are made, careful consideration should be given to the pros and cons of the different models. Such decisions should be based on the legal environment and institutional culture of the agency considering deployment, as well as the considerations listed above.

Actions Required for Resolution: Preparation of procurement plans by agencies deploying smart call boxes; also, enabling legislation may be required in some cases.

Issue: ***Ownership and Financing of Deployed Smart Call Box Systems***

Description: Who should fund deployment of smart call boxes? Who should own smart call box systems once they are deployed?

Raised by: Evaluator, RCT, Project Manager, Caltrans District 11, Caltrans Office of New Technology and Research, SAFE, Vendors

Seriousness: Potentially crucial to deployment.

Discussion: Successful deployment of smart call box systems will depend on the existence of funding sources adequate to cover their life cycle costs. In California, it may be possible in some cases to fund such systems on a local basis, using funds administered by the SAFEs. Outside California, and in areas in California for which SAFE funds are not available, other sources will need to be found.

Ownership of smart call box systems is also an issue. In California, it is most likely that both smart call boxes and regular call boxes will be owned by the SAFEs, regardless of whether the SAFEs or Caltrans finance them. A possible exception is cases in which "smart call boxes" are used for data transmission only. In this case, there is no compelling reason for the smart call box to be under the control of the same agency as the regular call boxes. Also, in some cases, smart call boxes may be owned by local agencies in California. Outside California, state transportation departments or local governments may own call box systems. Another possibility is for vendors to retain ownership of smart call boxes and to provide them under lease agreements with public agencies. This is already done in California in a few cases.

Emergency call box systems in California are funded by a special $1.00 vehicle registration fee imposed at the option of individual counties. Each county administers its call box program independently through a SAFE, although there are statewide guidelines governing both technical matters and relationships among the SAFEs, Caltrans, and the CHP. Decisions as to how to spend SAFE funds are the responsibility of the Boards of Directors of the SAFEs. By law, the top priority for SAFE funds goes to motorist assistance programs, but second priority goes to transportation management systems.

One option for funding the deployment of smart call box systems in California is to use SAFE funds. This could only be done on a county-by-county basis, with the approval of the local SAFE Board. SAFEs are unlikely to agree to fund smart call box applications, which are primarily of benefit to Caltrans, unless the financial needs of their other programs are already met. The extent to which this is likely to be the case depends heavily on population density: counties with large populations and relatively few miles of freeways tend to have surpluses, but less populous counties that are still involved in expanding their call box systems do not. Unless Caltrans can find other sources of funding for smart call boxes, they are likely to be deployed only in counties with surpluses of SAFE funds. Even in those cases, it will be necessary to convince the SAFE Boards that smart call boxes are a worthwhile investment.

A potential problem in California, then, is that decisions to deploy smart call boxes may be based more on the availability of funding than on cost-effectiveness. Outside California, local funding sources may not exist; where this is the case, it will be necessary for agencies to fund smart call boxes from their own resources.

An additional issue related to ownership and financing of smart call boxes is distribution of the data produced by them. Potential users include state departments of transportation, local agencies, metropolitan planning organizations, and private sector firms involved in ATIS activities. Within a state department of transportation, such as Caltrans, smart call boxes may be primarily associated with TMCs, but the data produced by them may be used by other divisions, including planning, maintenance, traffic census, etc. Arrangements, both physical and institutional, need to be worked out for the distribution of data and any corresponding payments to be made by data users.

Ways to Avoid or Mitigate Potential Problems: Financial planning needs to be undertaken prior to any decision to deploy smart call box systems. Such planning should include identification of sources of funds adequate to cover the life cycle costs of the system. Since this FOT was not entirely successful in determining maintenance costs, agencies should be conservative in making provision for these. In California, it also may be useful for the legislature to reconsider the call box funding system to balance out some of unevenness in call box coverage between densely populated counties and other areas. It may also be prudent for Caltrans to consider developing internal sources of funds for smart call box deployment. Agreements need to be worked out between smart call box providers and potential data users to determine the details of data distribution and any financial compensation that may be involved.

Actions Required for Resolution: Agencies considering smart call box deployment should undertake financial planning prior to deciding to go ahead and should consider the full range of options regarding their ownership. The California legislature should review the existing call box funding system to assess its overall effectiveness. Caltrans management should consider the possibility of financing smart call box deployment from internal funding sources. Agencies considering smart call box deployment should develop agreements with potential users concerning data distribution.

Issue: ***Market Size and Profitability***

Description: Is the potential market for smart call box applications large enough to provide a profit for firms developing systems?

Raised by: Evaluator, Vendors, Project Manager

Seriousness: Potentially crucial for deployment

Discussion: The entire market for call boxes is not large compared with the market for many other types of electronic equipment. The market for smart call boxes is expected to be even smaller. Meanwhile, profit margins on provision of call box systems appear to be modest. The eventual marketing of smart call boxes for deployment depends on whether this is seen as offering a reasonable opportunity for profit for the vendors.

Ways to Avoid or Mitigate Potential Problems: Develop as wide a market for smart call boxes as possible.

Actions Required for Resolution: Market research by vendors.

Issue: ***Structure and Business Practices in the Electronics Industry***

Description: Are there common structural factors and business practices of the electronics industry that, taken in conjunction with typical government procurement policies, might lead to problems in smart call box deployment efforts?

Raised by: Evaluator, Vendors, Project Manager, SAFE

Seriousness: Potentially serious in some cases

Discussion: The electronics industry (at least those portions involved with call boxes) consists of a number of rather units engaged in highly specialized lines of business. These highly-specialized units exist in an environment dominated by large parent firms, usually as subsidiaries or divisions of the parent firms. Ownership of the small units tends to change rapidly; in addition, because they are small and specialized, they are heavily dependent on subcontracting to obtain engineering expertise outside their specialized areas of competence.

The most obvious example of the revolving parent firm phenomenon in the Smart Call Box FOT was that the Project Manager had three corporate identities during the life of the FOT. In this particular case, the corporate identity changes seem to have had virtually no impact on the conduct of the test, except to raise a conflict of interest question at one point because one of the parent firms also owned a potential prime vendor. In another case, however, a conflict between a prime vendor and its principal engineering subcontractor had a serious impact on the vendor's performance. This conflict eventually resulted in the subcontractor taking over the prime vendor's call box business, although this did not take effect until after the end of the FOT. This situation illustrates both the vendor's vulnerability due to heavy dependence on subcontractors for engineering support and the hazards of an environment in which parent firms frequently trade specialized business units. Also, one of the prime vendors had such severe cash flow problems that work was sometimes halted when payments were late; this may in part have been a result of inadequate support from the parent firm.

The dependence on subcontractors is also illustrated by the large number of firms involved in the vendor "teams" that carried out the Smart Call Box FOT. In at least one case, there was evidence of inadequate communication within the "team," which may have had some impact on the results of the FOT. In this case, some of the subcontractors report being unaware of important test requirements until very late in the FOT, or being unaware of test results involving equipment they supplied.

In a deployment environment, the sorts of problems just described could have a serious impact. Those related to cash flow problems are likely to be worse in a normal government procurement environment than they were in the FOT. Government agencies are notoriously slow in processing contracts and in making payments. Because procurement for the FOT was administered by San Diego SAFE, it was exempt from normal state procurement regulations. It was the opinion of several of the participants that, as a result, the FOT was exceptionally prompt in paying the vendors. In addition, problems involving lack of communication between prime contractors and subcontractors or loss of engineering support due to conflicts with subcontractors could obviously have a negative effect on the performance of deployed smart call box systems.

Ways to Avoid or Mitigate Potential Problems: It is probably not possible to avoid all problems of this sort. Government agencies must be prepared for such problems and need to react to them as quickly as possible when they arise. It may be prudent to investigate the qualifications of potential vendors prior to entering into contracts with them; these investigations should include the financial health of the firm, the policies and commitment to the project of the parent firm (if applicable), and the extent to which the vendor is dependent on subcontractors for key services needed to carry out the contract.

Actions Required for Resolution: To whatever extent their procurement regulations permit, agencies deploying smart call boxes should carefully investigate the qualifications of prospective vendors and give preference to those with adequate resources and commitment to the project.

Issue: ***Intellectual Property Rights***

Description: Who should own intellectual property rights to products developed as part of the Smart Call Box FOT?

Raised by: Evaluator, RCT, FHWA, Caltrans Office of New Technology and Research

Seriousness: Potentially serious

Discussion: Since the systems developed by the Smart Call Box FOT were produced by a public-private partnership, there was a potential issue as to how intellectual property rights should be distributed between the public sector and private sector participants. The distribution of intellectual property rights, in turn, could serve as either an incentive or a disincentive for further development of smart call box systems. The RCT adopted a policy that it would not acquire intellectual property rights to any products developed as a part of the FOT. This was intended to leave the vendors free to develop their systems as proprietary systems, and was intended to encourage them to further develop and market them.

Ways to Avoid or Mitigate Potential Problems: Not applicable.

Actions Required for Resolution: Not applicable.

Issue: ***System Compatibility Issues***

Description: How should systems in which different vendors supply smart call boxes and regular call boxes be managed?

Raised by: Evaluator, Caltrans District 11

Seriousness: Moderate

Discussion: Where smart call boxes are deployed in conjunction with existing call box systems, it is expected that the majority of the call boxes will be regular (voice-only) call boxes. In some cases it may be desirable to obtain smart call boxes from a vendor other than the one supplying the regular call boxes. In these cases, agencies deploying smart call boxes need to consider the extent to which the two systems are compatible. In addition, a compatibility issue may arise if future improvements in smart call box systems increase the attractiveness of a particular vendor's product, since it may be desirable to add new smart call boxes produced by one vendor to a system consisting of call boxes supplied by another vendor.

Several sorts of incompatibility may result. 1) The physical appearance of the call box cabinet for the smart call boxes may be different, and this could be confusing to the public. This is not likely to be a major problem in the case of the California call box vendors, since the appearance of both systems is similar. 2) Call boxes are normally monitored by maintenance computers. In the case of private-sector-model systems, this monitoring is provided by the vendors, and it is unreasonable to expect one vendor to monitor call boxes provided by another. In public-sector-model systems, monitoring will probably be provided by the agency owning the call boxes, but software incompatibilities may preclude use of a single maintenance computer for systems provided by different vendors. Indeed, based on the experience of this FOT, separate maintenance computers may be required for smart call box systems, even if they are supplied by the same vendor. 3) If smart call box systems produced by different vendors are used for the same data collection function (say, two different traffic census systems), separate software packages, and possibly separate computer systems, will be required for collection of data at the TMC. 4) If maintenance is provided in-house, maintenance requirements may become more complicated and expensive.

Ways to Avoid or Mitigate Potential Problems: 1) Use a single vendor for all types of call boxes; however, this may be undesirable for a number of reasons. 2) Develop a single standard for the appearance of call box cabinets for future systems; this will not eliminate the potential for incompatible appearance in existing systems, however. 3) Plan on purchasing and operating separate maintenance computers for systems supplied by different vendors; also consider use of separate maintenance computers for regular and smart call boxes even where they are supplied by the same vendor. 4) Enter into maintenance contracts in which each vendor is responsible for maintaining its own equipment (see discussions of maintenance issues that follow)

Actions Required for Resolution: 1) Study need for compatibility of call box cabinet appearance. 2) Include an adequate number of maintenance computers and data collection systems in system plans.

Issue: ***System Maintenance for Private-Sector-Model Systems***

Description: How can proper maintenance of deployed private-sector-model smart call box systems be assured?

Raised by: Evaluator, Caltrans District 11, SAFE

Seriousness: Moderate

Discussion: Under the private-sector procurement model, maintenance is provided by vendors under contract. Vendors would normally be expected to maintain equipment they has supplied themselves. Timeliness and quality of maintenance may be affected by factors such as the size of the local smart call box system and its distance from the vendor's base of operations. It was the experience of the FOT that out-of-town vendors did not always respond to problems promptly. This problem is likely to be more severe for small systems.

Ways to Avoid or Mitigate Potential Problems: 1) Avoid hiring out-of-town vendors; however, this will usually be impractical. 2) Include incentives for prompt response in maintenance contracts.

Actions Required for Resolution: Develop incentive clauses for prompt response, include these in vendor maintenance contracts, and observe response over time.

Issue: ***System Maintenance for Public-Sector-Model Systems***

Description: How can proper maintenance of deployed public-sector-model smart call box systems by assured?

Raised by: Evaluator, Caltrans operational personnel

Seriousness: Potentially serious

Discussion: Under the public-sector procurement model, maintenance is provided in-house by the agency owning smart call boxes. Issues which must be resolved include 1) What organizational unit will be responsible for smart call box maintenance and how will it be related to the TMC? 2) What range of equipment will a single unit be expected to maintain? and 3) What maintenance training needs to be provided?

Organizational structures employed by transportation agencies for the maintenance of electronic equipment vary widely, as do (apparently) the timeliness and quality of the resulting maintenance. It is important that the unit maintaining smart call boxes be assigned a reasonable workload, and that lines of accountability be such that it is responsive to the needs of the TMC. It is also important to recognize that deployment of smart call box systems will probably increase the variety of equipment requiring maintenance. For instance, it may be necessary to maintain several brands of traffic counters or several types of weather sensors. It is important that careful consideration be given to the possible impact of this increase in complexity on the cost and quality of maintenance, and that adequate training be provided for maintenance personnel.

Ways to Avoid or Mitigate Potential Problems: 1) Consider maintenance contracts with vendors, even if system management is provided in-house. 2) Assign responsibility for supervision of maintenance of smart call box systems to the TMC. 3) Provide adequate training for maintenance personnel working on smart call box systems.

Actions Required for Resolution: 1) Address maintenance issues in deployment planning. 2) Provide required training to maintenance personnel. 3) Provide adequate staffing for units maintaining smart call box systems.

Issue: ***Community Concerns***

Description: To what extent might community concern with esthetics, etc. limit deployment of smart call box systems?

Raised by: Community groups, RCT

Seriousness: Moderate

Discussion: In the course of the FOT, there were at least two instances in which community groups expressed concern about the location or appearance of equipment used in the FOT. Similar concerns may be expected in the case of deployed systems. In particular, the towers used to mount weather sensors and video cameras are a possible source of community concern. Community opposition may limit locations in which these particular subsystems can be located, and this in turn, may decrease the value of the data. In the case of both video surveillance cameras and weather sensors, locations are dictated by the need to observe particular areas. In some cases, it may not be possible to find unobtrusive locations that provide the necessary coverage.

Ways to Avoid or Mitigate Potential Problems: Discuss deployment plans with community groups prior to deployment. Try to find hardware (such as towers for mounting equipment) that is as esthetic as possible.

Actions Required for Resolution: System deployment may require environmental impact statements or reports. Public relations efforts need to be sensitive to esthetic issues and other possible community concerns.

Issue: ***Environmental Impact Documentation for Deployment***

Description: Will Environmental Impact Statements or Reports be required for deployed smart call box systems?

Raised by: Evaluator

Seriousness: Moderate

Discussion: As a governmental action, the deployment of a smart call box system by a public agency would seem to fall under laws such as the National Environmental Protection Act (NEPA) or (in California) the California Environmental Quality Act. If there is any Federal financial participation, NEPA will probably apply; if not, documentation may still be required under state law. It is not known whether smart call box projects will qualify for exemptions, or whether they will be held to have no significant adverse impacts. Given the community concern about the appearance of some of the equipment installed as a part of this FOT, it is likely that significant adverse environmental impacts will be held to exist, at least in some cases. Agencies proposing to deploy smart call boxes will need to research the need for environmental impact documentation and produce any needed documentation prior to deployment.

Ways to Avoid or Mitigate Potential Problems: Research environmental impact reporting requirements for past call box, weather reporting, and video surveillance projects. Be prepared to produce any necessary documentation.

Actions Required for Resolution: Research law with regard to necessity of Environmental Impact Statements of Reports under state and Federal law. Prepare documents if necessary.

Issue: ***Assignment of Risk for Theft, Vandalism, and/or Accidental Destruction of Equipment***

Description: Who should assume the financial risk for theft, vandalism, and/or accidental destruction of equipment for deployed smart call box systems?

Raised by: Evaluator (based on concerns expressed by vendors)

Seriousness: Moderate

Discussion: Call box systems involve valuable equipment that is sometimes attractive to thieves, and which is located in an environment where it is vulnerable to vandalism and accidental destruction. Smart call boxes add several components (such as video cameras and weather sensors) that may be especially attractive to thieves or especially vulnerable to damage. Under some ownership and procurement options, there may be an issue as to how the financial risk for loss of equipment due to these causes should be assigned. In most cases, the owner of the system would be expected to assume such risks. An exception might be systems supplied under lease agreements, in which the public agency leasing the call boxes might assume some or all of this risk.

Ways to Avoid or Mitigate Potential Problems: Consider the issue of risk for theft, vandalism, and/or accidental destruction of equipment when developing deployment plans and implementation contracts.

Actions Required for Resolution: Include issue in contract negotiations and resolve prior to issuing contracts.

Issue: ***Encroachment Permits for Deployment***

Description: How can permit requirements be properly enforced in system deployment?

Raised by: RCT, Project Manager, Caltrans District 11

Seriousness: Minor (unless call box assemblies fail crash rests)

Discussion: Encroachment permits are required for installation of call boxes in public highway right-of-way. Where call boxes are installed in clear zones, crash testing is required and call boxes must be designed in such a way as to minimize damage to vehicles in the event of a collision. Existing call boxes employed in California have already been subjected to crash testing and approved for installation in clear zones. It is believed that all modified call box assemblies produced as part of this FOT will continue to qualify for installation in California under existing permits. States other than California may have different requirements, however, or may require additional evidence of crash worthiness.

Some system components, such as weather sensors and some video cameras, were mounted on towers that do not meet standards for installation in the clear zone, unless protected by barriers or guardrails. These were installed outside the clear zone.

In addition, work performed in public right-of-way by persons other than Department of Transportation employees requires permits. Activities such as installation and maintenance of call box equipment normally require these permits.

Finally, in some cases, compliance with the Americans with Disabilities Act may require modifications to the physical design of call box assemblies.

It was the experience of the FOT that the vendors, even though they were used to working under permits, did not always seem to understand the importance of following their conditions strictly. In addition, vendors complained about the amount of red tape involved in the permit application process and seemed sometimes not to understand it.

Ways to Avoid or Mitigate Potential Problems: Make sure vendors are fully aware of permit requirements and closely monitor compliance. Investigate status of crash worthiness certification for smart call box assemblies before committing to deployment, and be prepared for substantial delays in the event crash testing is required. If possible, locate components other than call box assemblies outside the clear zone.

Actions Required for Resolution: 1) Investigate requirements for crash testing prior to committing to deployment of smart call box systems. 2) Emphasize permit requirements to vendors at a pre-installation conference. 3) Monitor vendor compliance with permit requirements, especially during the equipment installation phase.

Issue: ***Fusion of Smart Call Box Data with Other TMC Data***

Description: How can data produced by smart call boxes best be incorporated into the databases of TMCs and other users?

Raised by: Project Manager, Caltrans Office of New Technology and Research

Seriousness: Minor

Discussion: Some of the characteristics of data produced by smart call boxes may differ from those of other data in TMC databases. For instance, traffic data from smart call boxes is reported on as non-continuous basis, and in some cases may consist of alarm signals only. Meanwhile, TMCs have little experience in handling data such as hazardous weather alarms. There needs to be planning to determine how smart call box data will be incorporated into existing databases of TMCs and/or other agencies.

Ways to Avoid or Mitigate Potential Problems: Undertake planning to determine the best way to handle, store, and distribute data from smart call box systems.

Actions Required for Resolution: TMCs and other prospective users of smart call box data should plan for the incorporation of the data in their databases prior to the deployment of smart call box systems.

Issue: ***Contracts with Cellular Carriers***

Description: Do current contracts between SAFEs and cellular carriers permit data transmission as well as voice transmission?

Raised by: Vendor

Seriousness: Minor, except that it could impact cost of deployment

Discussion: Existing contracts between SAFEs in California and cellular carriers provide for service at a major discount when compared with that offered to the general public. Current contracts may be written in such a way as to cover voice communications only. Contracts may need to be renegotiated in order to add the data communications involved in smart call box systems.

Ways to Avoid or Mitigate Potential Problems: Negotiate contracts with cellular carriers providing for both voice and data communications.

Actions Required for Resolution: SAFEs in California need to review their contracts with cellular carriers prior to deploying smart call box systems and renegotiate them if they do not allow data communications.

ISSUES RELATED TO THE CONDUCT OF THE FOT

Issue: ***Role of the Vendors***

Description: What role should the vendors have played in the Smart Call Box FOT?

Raised by: Evaluator, PATH, Project Manager

Seriousness: Serious

Discussion: Vendors were involved in this FOT through an arms-length relationship, in which they were under contract to the FOT Partners. An alternative would have been to bring them into the original proposal as full partners.

The main advantages of the arrangement followed in this FOT appear to have been that 1) It simplified the process of preparing the FOT proposal. Given the time allowed for proposal preparation, it might have been difficult to involve prospective vendors at this stage. 2) It may have helped preserve the vendor's proprietary rights to the systems they developed; however, this could probably have been done anyway by addressing the issue in a partnership agreement that included the vendors. Major disadvantages were: 1) The process of setting up the vendor contracts was very time consuming. This process included issuance of an RFP, preparation of proposals by the vendors, review of these proposals by the RCT, negotiations between the RCT and the vendors concerning technical issues and the scope of the test, and negotiations over contract language. In all, these activities consumed over a year. 2) The realism of some of the items included in the FOT proposal was questionable. Much of this could have been avoided by involving prospective vendors from the beginning.

Ways Problems Could Have Been Avoided or Mitigated: Vendors could have been included in the FOT proposal as partners. In that event, the partnership agreement should have included language protecting the rights of the vendors to products they developed, and giving the other partners recourse in the event a vendor failed to prosecute FOT-related work diligently.

Issue: ***Role of the Project Manager***

Description: What role should the Project Manager have played in the Smart Call Box FOT?

Raised by: Evaluator, FHWA, Project Manager, SAFE, Caltrans Office of New Technology and Research

Seriousness: Moderate

Discussion: The original proposal for this FOT was written by employees of Titan Corporation on behalf of the FOT partners. Over the course of the FOT, this particular entity underwent a number of corporate changes, eventually becoming T- Cubed. Nevertheless, the individuals who were involved in writing the FOT proposal were also involved in managing the project throughout its history.

This was a somewhat unusual arrangement, and drew comment from several of the other participants in the field test. The sponsoring agencies saw the involvement of a private-sector consulting firm as Project Manager as both a potential strength and a potential weakness. On the one hand, they believed that the organization and direction of the project was stronger than it would have been otherwise. On the other hand, they were aware that the use of a consulting firm as Project Manager was expensive, and were concerned that T-Cubed might have been pursuing its own interests in the development of call box technology at the expense of what would been more in the interests of Caltrans.

Given the fact that the Project Manager wrote the proposal, it is hard to see how it could have been excluded from the project subsequently. Nevertheless, there was a perception on the part of some members of the SAFE board of directors that it might constitute conflict of interest to award a project management contract to a firm that had proposed a project, and, in fact, T-Cubed was not guaranteed participation in the FOT. The public agency partners went though a process of advertising for a Project Manager after the FOT was funded. Although T-Cubed was ultimately selected, this created unnecessary uncertainty.

Ways Problems Could Have Been Avoided or Mitigated: The Project Manager could have been included in the partnership. In this event, the partnership agreement should have addressed the specific duties of the Project Manager and given the other partners recourse in the event the Project Manager failed to perform adequately.

Issue: ***Role of the Evaluator***

Description: What involvement should the Evaluator have had in the planning and administration of the FOT?

Raised by: Evaluator, PATH

Seriousness: Moderate

Discussion: The intent of the FOT program was that evaluations should be "independent." In particular, this meant that the organization conducting the evaluation would normally not be directly a part of whatever partnership was conducting the FOT. This necessitated a separate contracting arrangement. In addition, in this FOT, it meant that the Evaluator was not identified prior to submission of the proposal and had no input into the original FOT proposal.

Results of this arrangement were: 1) There were serious delays in the processing of the evaluation contract. For the most part, these did not actually impede the progress of the FOT because the Evaluator performed work before it was actually under contract, but they were annoying, created uncertainty, and delayed the official issuance of some of the evaluation documents. 2) The Evaluator was not involved in the development of the FOT proposal. As a result, evaluation issues were neglected in the proposal. Later, when it came time to produce the Evaluation Plan, it was sometimes difficult redirect the FOT so that it focused on clearly defined issues that could be evaluated. For example, there were no performance standards (supposedly the basis for system specifications and measures of effectiveness) until shortly before submission of the vendors' proposals, approximately a year after the FOT was funded and six months after active work began on it.

Ways Problems Could Have Been Avoided or Mitigated: 1) The Evaluator should have been identified prior to the submission of the FOT proposal and should have been involved in preparation of the proposal. Proposals should not have been funded without a clear (but concise) description of what was to be demonstrated and how it would be evaluated. This description should have been prepared (or at least endorsed) by the Evaluator. 2) Evaluation contracts should have been either subcontracts of the FOT contract or else issued simultaneously. If the evaluation contract had been a subcontract of the FOT contract, the Evaluator's independence could have been preserved by having the Evaluator report directly to FHWA for review and approval of evaluation documents and reports, as was actually done.

Issue: ***State versus Local Control of the FOT***

Description: To what extent should the FOT have been controlled locally as opposed to being controlled at the state level?

Raised by: Caltrans District 11, Caltrans Office of New Technology and Research, PATH

Seriousness: Moderate

Discussion: This FOT was unique in California in that it was the only one where effective control of the FOT was maintained at the local level instead of being given to Caltrans Office of New Technology and Research. This decision, which resulted from a firm policy on the part of Caltrans District 11 not to participate in such efforts unless they were locally controlled, was understandably controversial. Many participants felt that this was a major strength in the organization of the FOT and that it contributed particularly to the early and "successful" completion of the test. At least one representative of Caltrans Office of New Technology and Research, on the other hand, believes that the local control weakened the potential technical accomplishments of the FOT. The "power struggle" over control of the project did affect the conduct of the FOT in a minor way by creating a communications barrier between the project and the Office of New Technology and Research.

Ways Problems Could Have Been Avoided or Mitigated: Ideally, Caltrans Office of New Technology and Research would have had more opportunity for technical input, without actual control. Timely communication with the RCT as a whole could have facilitated this. Eventually, the Office of New Technology and Research did send observers to the RCT meetings, but this should have been done much sooner.

Issue: ***FOT Contracts***

Description: How should FOT contracts (other than those with vendors) have been structured and processed?

Raised by: Evaluator, RCT, Caltrans Office of New Technology and Research

Seriousness: Serious

Discussion: Four contracts were required to implement the Smart Call Box FOT: 1) a contract between FHWA and the State of California; 2) a contract between the State of California and San Diego SAFE, acting on behalf of the FOT partners; 3) a contract between the partners and the Project Manager; and 4) the evaluation contracts between the State of California and PATH and PATH and SDSU. Processing of these contracts was very time consuming. As a result, the start of active work on the FOT was delayed by at least six months, and the Evaluator was called upon to perform work without a contract for more than six months thereafter.

A major reason for these delays was a tendency to process contracts in series. In addition, the contracting procedures of all the agencies involved (especially Caltrans) appear to be unnecessarily uncertain and cumbersome. It took six months for Caltrans to process the agreement with SAFE setting up the FOT. The Caltrans Office of New Technology and Research did not begin to process the evaluation contract until after the contract with SAFE had been finalized. Again, the whole process of having Caltrans issue the contract and PATH issue the subcontract to SDSU took more than six months. Further, this contract was threatened by an Executive Order from the Office of the Governor of California that forbade issuance of sole-source contracts; a waiver was eventually obtained, but this added to the delay and uncertainty.

Ways Problems Could Have Been Avoided or Mitigated: 1) A different organizational structure, as discussed under "Role of the Evaluator" and "Role of the Project Manager" could have reduced the number of contracts required. 2) Contracts could have been processed simultaneously. 3) Top management of Caltrans, the County of San Diego, and other agencies involved in processing agreements for the FOT could have been more conscious of the harm done by inefficient processing of contracts and done something to speed up the process. 4) The Office of the Governor could have been more reasonable in its approach to the problems created by sole-source contracting in California.

Issue: ***Vendor Contracts***

Description: What provisions were appropriate for contracts between the FOT Partners and the vendors?

Raised by: RCT, Vendors, Project Manager

Seriousness: Serious

Discussion: San Diego SAFE acted on behalf of the FOT partners in establishing contracts with the vendors. The SAFE is an agency of the County of San Diego, and based the original drafts of these contracts on standard County agreements. A number of the clauses retained from these standard agreements were resisted by the vendors (particularly GTE) and this resulted in protracted contract negotiations.

The most important issues were: 1) The payment schedule, 2) Issues related to schedule enforcement, 3) RCT approval of the vendor's project manager, and 4) The relative roles of SAFE and the RCT.

The original drafts of the contracts provided for payment on completion of milestones, and made no provision for any mobilization expenses. Vendors favored monthly payment based on submission of progress reports. Contract language was modified to allow for mobilization payments but retained payment for completion of milestones.

A major dilemma in devising the contract language was how to recognize that the project was a test, in which the failure of particular types of systems was a legitimate outcome, while at the same time ensuring that the vendors would pursue their work diligently. In particular, the RCT wanted to have recourse in the event a vendor failed to meet the schedule due to lack of effort. Original contract drafts included a provision for liquidated damages of $500 per day in the event vendors failed to complete work within the time prescribed. Both vendors objected to this provision on the grounds that the amount of system integration involved in the project created a level of uncertainty that was incompatible with it. This provision was deleted, which left the RCT in the position of relying on provisions related to use of inspections to ensure the timelines and quality of work. GTE suggested a number of changes in these provisions, including language to the effect that failure to complete any and all tasks, using best efforts, should relieve the vendor from further financial responsibility. The RCT, on the Project Manager's recommendation, insisted that "best effort" be defined as completing the scope of work outlined in the contract within the time allotted by the schedule.

Original drafts of the contracts required the approval of the RCT in the event that a vendor reassigned its project manager. This language was intended to protect the project against instability in staffing on the part of the vendors. GTE objected to this provision, and the RCT reluctantly deleted it from the GTE contract.

GTE also expressed concern because both the SAFE Director and the RCT had a role in the administration of the contract. This was resolved naming SAFE as the contracting party, with the understanding that the SAFE Director would follow the recommendations of the RCT regarding technical matters.

Of these issues, that of ensuring schedule adherence in an inherently risky project turned out to be the most critical to the actual conduct of the test. Despite the haggling over the right to approve changes in project managers, neither vendor attempted to reassign its project manger. The provision of a mobilization payment seemed to relieve most of the vendors' concern about the payment schedule. Also, there was never any real confusion in the roles of the RCT and the SAFE Director.

There was, however, a general failure on the part of the vendors to adhere to schedules, which at one point led to issuance of notices to cure default to both vendors. In addition, the Project Manager and the RCT are on record as having questioned GTE's motivation to keep schedules on more than one occasion. Despite this, the real problem with the schedules was not so much the contract language as the RCT's reluctance to enforce it. For instance, several of the "firm" deadlines established by the "cure notices" were in fact violated without any real consequences. The RCT was trying to maximize the FOT's contribution to the development smart call box technology and was thus reluctant to cancel subtests so long as there was any hope that they would succeed, even if this compromised certain other aspects of the FOT, such as the evaluation of system reliability.

Ways Problems Could Have Been Avoided or Mitigated: 1) More attention could have been given to the requirements of the FOT as opposed to typical County projects in the initial drafts of the contracts. 2) A different organizational concept, in which vendors were included as FOT partners, could have eliminated altogether the need for arms-length contracts. This would not have completely solved the issue of vendor motivation to keep schedules, but it probably would have eliminated some of the delays involved in negotiating and processing the contracts (see discussion of Role of Vendors). 3) Strict enforcement of schedule adherence an early stage might have encouraged more diligence on the part of both vendors; however, it appears that much of the schedule slippage was due to unexpected technical difficulties rather than a lack of vendor motivation.

Issue: ***Evaluation Guidelines***

Description: Were the Evaluation Guidelines prepared by MITRE Corporation for FHWA appropriate for this FOT?

Raised by: Evaluator

Seriousness: Moderate

Discussion: Evaluations of FOTs were carried out under a set of guidelines prepared by the MITRE Corporation, acting as consultants to FHWA. These guidelines are written in highly generic terms and require an elaborate set of evaluation documents, including evaluation plans, individual test plans, and data management plans.

It was the experience of the Evaluator of this FOT that the MITRE guidelines were too generic to be of any real benefit. Also, in several instances they were confusing. Finally, they required elaborate evaluation plans to be prepared prematurely. It was important for the Evaluator to be able to convey the basis of and procedures for the evaluation to FHWA, but it would have been more appropriate if this had been done after negotiations with the vendors had established clearly the proposed scope of the FOT and the details of the proposed test systems.

Ways Problems Could Have Been Avoided or Mitigated: Instead of developing elaborate evaluation guidelines (which were issued after FOT proposals had been submitted) FHWA could have required that proposals describe clearly what test systems were expected to accomplish and how this could be evaluated. This would have required a different fundamental organization for the FOTs, in which Evaluator would have been identified prior to submission of proposals and involved in their preparation (see discussion of Role of Evaluator). Such a policy could have resulted in more flexibility for evaluations to respond to the goals of individual FOTs, and would have allowed FHWA to assess the adequacy of evaluation plans prior to committing funds.

Issue: ***Communication Between RCT and Sponsoring Agencies***

Description: Were provisions for communication between the RCT and the sponsoring agencies adequate?

Raised by: Project Manager, RCT

Seriousness: Minor

Discussion: Initial provisions for communication between the RCT and the sponsoring agencies called for reports to be forwarded sequentially from the RCT to the Caltrans Office of New Technology and Research, FHWA California Division, FHWA Region 9, and FHWA Headquarters. This system proved ineffective: there were complaints by FHWA California Division that reports were not reaching it in a timely fashion. This problem was solved by having reports sent simultaneously to all offices that were supposed to receive them. In addition, FHWA requested that progress reports be submitted via e-mail, and this was done.

Ways Problems Could Have Been Avoided or Mitigated: Reports could have been distributed simultaneously from the beginning.

Issue: ***Potential Conflict of Interest***

Description: Resolution of potential conflict of interest on part of the Project Manager

Raised by: San Diego County Counsel

Seriousness: Minor

Discussion: Titan Corporation was selected as Project Manager. Just prior to the completion of the interagency between the State of California and San Diego SAFE, Titan sold the traffic-related portion of its business to RMSL Traffic Systems, Inc. and subcontracted management of the Smart Call Box FOT to RMSL. Denbridge Electronics was the parent company of RMSL and also of U. S. Commlink, at that time a potential vendor. The San Diego County Counsel raised the issue of whether this relationship constituted a conflict of interest. After studying the issue, the County Counsel concluded that the relationship between RMSL and U. S. Commlink was not close enough to give rise to a conflict of interest.

In addition, some members of the SAFE Board of Directors expressed concern that it would constitute conflict of interest to award the project management contract to the firm that had written the project proposal (see discussion of role of the Project Manager).

Ways Problems Could Have Been Avoided or Mitigated: Not applicable.